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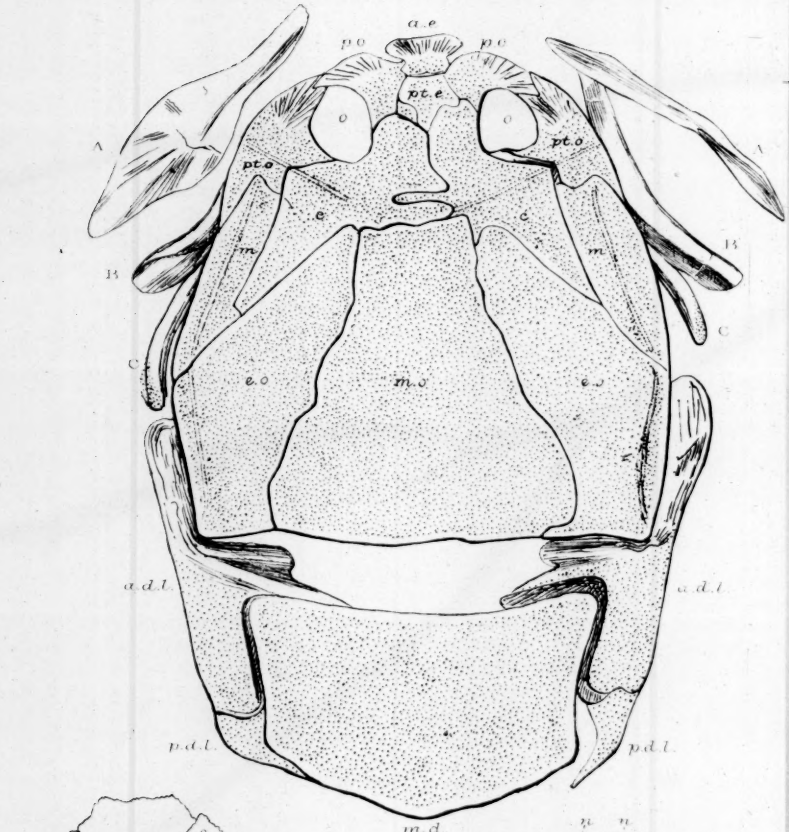

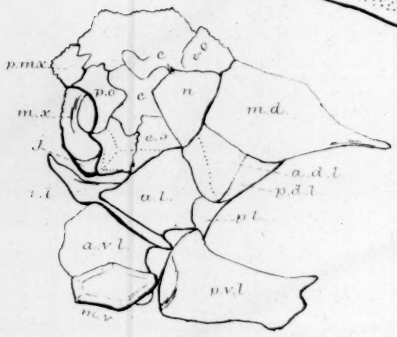

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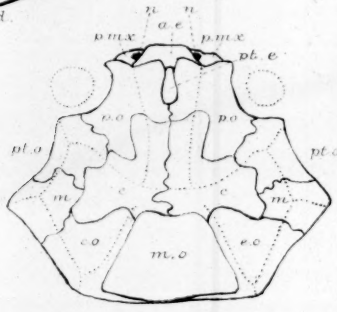

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R.H. Traquair del.
E.C. Woodward lith.

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1. Homosteus. 2, 3. Coccosteus.

THE

GEOLOGICAL MAGAZINE.

NEW SERIES. DECADE III. VOL. VI.

No. I.—JANUARY, 1889.

ORIGINAL ARTICLES.

I.—*Homosteus*, Asmuss, compared with *Coccosteus*, Agassiz.

By Dr. R. H. Traquair, F.R.S., F.G.S.

(PLATE I.)

THE creature which forms the subject of the present communication is the same as that which was described as *Asterolepis* by Hugh Miller in his "Footprints of the Creator," and consequently its remains are at present better known to British geologists and palæontologists under that name. Why, then, alter a name which we have used so long? is a question likely to be asked by those who have not critically studied the complicated mesh in which the synonymy of the name "*Asterolepis*" is entangled.

The genus *Asterolepis* was proposed by Eichwald in 1840[1] for fragmentary remains of the exoskeleton of a vertebrate organism, from the Russian Devonian rocks, allied to *Pterichthys*, Ag. To these remains Agassiz also applied the name *Chelonichthys*, which he subsequently withdrew in favour of *Asterolepis* as having priority; and with them he also identified generically certain large bones and plates from the Lower Old Red of Dorpat, some of which were first figured by Kutorga[2] as "*Trionyx*" and "*Ichthyosauroides*," and of which a considerable number, collected by Asmuss, were reproduced in plaster and copies sent to Agassiz. A number of these casts were figured by Agassiz,[3] as of bones of "*Asterolepis*," some of which are generically identical with the creature of whose bones and cranial buckler many fine specimens from Thurso, largely collected by Robert Dick, came into the possession of Hugh Miller. And thus it was that these remains came to be figured by Hugh Miller as belonging to *Asterolepis*, although they had no affinity to the creature to which Eichwald originally gave that name, their identification with which being entirely due to a mistake of Agassiz, misled as he was by their mere external sculpture, consisting of small tubercles with stellate bases.

For, that "*Asterolepis*" cannot be applied to any of the remains from Dorpat represented by these casts, is unconsciously shown by

[1] Die Thier- und Pflanzenreste den alter rothen Sandsteins und Bergkalks in Nowgorodschen Gouvernement," Bull. Acad. Imp. St. Pétersburg, tome vii. p. 78.

[2] Beiträge zur Geognosie und Palaeontologie Dorpats, 1835-37.

[3] Poiss. Foss. du vieux Grès rouge, tab. xxxii.

Agassiz himself, isasmuch as he figured as "*Asterolepis ornata*," Eichwald, a nuchal or median occipital plate of unmistakeable Pterichthyan character,[1] apparently quite unaware of the significance of its shape. Nevertheless Agassiz in some controversial remarks on the subject insisted that his *Chelonichthys* (= *Asterolepis*) had nothing to do with *Pterichthys*![2]

Now, in 1856, Asmuss published a thesis[3] in which he minutely described the Dorpat fossil bones, including the subjects of the aforesaid casts, and made out of them two genera, *Homosteus* and *Heterosteus*, with many species. In the former of these two, namely *Homosteus*, Hugh Miller's fish, the so-called "*Asterolepis* of Stromness," is clearly to be recognized.

Upon these facts Pander insists in his "Placodermen," and not only did he propose to replace "*Asterolepis*" by *Homosteus* in the case of Hugh Miller's fish, but believing *Asterolepis*, Eichw., to be altogether identical with *Pterichthys*, Agassiz, as the name is undoubtedly prior, he proceeded to cancel the latter name altogether.

Naturally Pander's views excited opposition in this country, where the names brought into use by Agassiz and Hugh Miller had become classic through the writings of these distinguished men. Sir Philip Egerton, who does not seem to me to have thoroughly understood the situation, fiercely combated the proposals of Pander in the following words: "Having read both sides of the question with great care, my own impression is that Prof. Eichwald may perhaps have included in his genus *Asterolepis* some fragments which he subsequently ascertained (through the more perfect Scotch specimens sent to Russia by Dr. Hamel) to belong to the genus *Pterichthys* of Agassiz, and hence discarding the majority, namely, *Asterolepis* proper, assigns this name to the minority, to the exclusion of the Agassizian name. In the mean time Prof. Agassiz, then engaged upon his 'Poissons Fossiles du vieux Grès Rouge,' received through Prof. Brown, from Eichwald himself, specimens of his *Asterolepis*, which had no reference to *Pterichthys*, but were identical with the genus *Chelonichthys* established upon specimens brought over from Russia by Sir Roderick Murchison, and of which other specimens were found in the Orkney beds. On making this discovery he at once relinquished his own name, *Chelonichthys*, and adopted *Asterolepis* of Eichwald. If now it is sought to supersede *Pterichthys* of Agassiz by *Asterolepis* of Eichwald, it is surely just that the term *Chelonichthys* should be retained for Eichwald's *rejectamenta*, rather than *Homosteus* of Asmuss, a name of much later date than that of Agassiz."[4]

But whatever the specimens from the Orkney beds may have been, if any one will only compare Agassiz's own figure of *Asterolepis ornata*, Eichwald ("Old Red," tab. 30, fig. 5), with the plate No. 10 in Pander's restoration of the same species ("Placodermen," tab. 6,

[1] *Op. cit.* tab. xxx. figs. 5, 6.
[2] *Op. cit.* appendix, p. 152.
[3] Das vollkommenste Hautskelet der bisher bekannten Thierreiche, Dorpat, 1856.
[4] Quart. Journ. Geol. Soc. vol. xvi. 1859, p. 122.

fig. 1), he will see that this specimen at least, far from having "no reference to *Pterichthys*," is the median occipital plate of a very closely allied form indeed. Without injustice to the memory of Sir Philip Egerton, to whom palæichthyological science is indebted for so much valuable work, it is clear that he had not sufficiently gone into this question at least, as the fact above noted was dwelt upon by Pander himself (*op. cit.* p. 16).

On the Continent, however, the name *Homosteus*, Asm., has been adopted for Hugh Miller's fish, and reasons have also been found for maintaining *Pterichthys* and *Asterolepis* as distinct genera, in a supposed difference in the articulation of the arms. In the previous volume of this MAGAZINE[1] I have shown that this supposed diagnostic mark is untenable, at the same time that I have sought to establish another on the mode of articulation of the anterior median dorsal plate.

But Agassiz's work, in which he classified "Asterolepis" among his "Cœlacanthi," a group generally equal to the Cycliferous Crossopterygii of more recent times, was the means of drawing Hugh Miller into mistakes of much greater importance than mere nomenclature. Accordingly, as Pander pointed out, Miller attributed to his *Asterolepis* "the teeth of *Dendrodus* and the scales of *Glyptolepis*," and made a very formidable creature out of it, ten to thirteen feet in length; indeed, referring one of the large Russian plates (*Heterosteus*, Asmuss) to the same genus, he calculated a length of eighteen to twenty-three feet for the entire fish. And his non-recognition of the true affinities of the creature led also to other mistakes in the identification of bones, to which allusion will be made in due course.

By Asmuss *Homosteus* and *Heterosteus* were placed in a family by themselves, *Chelonichthyda*, in a somewhat heterogeneous group of "Ganoidea loricata," the other families herein included being Spatularida, Acipenserida, Coccosteida, Pterichthyda, and Cephalaspida. As regards *Homosteus*, though, as Pander remarks, it is wonderful how, without knowledge of Hugh Miller's drawings or description, he was able to fit together the isolated plates at his disposal, yet, unacquainted with the orbits, he supposed the cuirass to belong exclusively to the body, and also entirely reversed its position on the animal.

Pander, however, classified *Homosteus* in McCoy's group of Placodermata and rightly gave it a place immediately after *Coccosteus*, interpreting as its median dorsal plate the one considered by Hugh Miller to be a "hyoid," and supposed by him to occupy a place between the rami of the jaws. This supposed hyoid plate was known to Hugh Miller only in an isolated form, but it fell to the lot of the late Mr. John Miller, of Thurso, to record a specimen in which it occurred in its natural position on the back behind the head, and so with absolute certainly to confirm Pander's view of the case. Mr. John Miller's collection having some years ago passed

[1] Notes on the Nomenclature of the Fishes of the Old Red Sandstone, GEOL. MAG. Dec. III. Vol. V. 1888, p. 508.

into the possession of the Museum of Science and Art, Edinburgh, I propose to make this, the most perfect specimen of *Homosteus* which has ever been found, the text of the following remarks on the genus.

Along with *Homosteus* it may, however, be as well to re-examine the structure of *Coccosteus* itself as a basis of comparison.

The reading of the cranial buckler of *Coccosteus* is much complicated by the fact that certain superficial grooves belonging to the lateral-line system are very conspicuous and apt to be mistaken for sutures, while the true sutures are visible with difficulty, and can only be made out in exceptionally well-preserved examples. They seem, indeed, to have almost entirely escaped the observation of Agassiz, as the lines on the head indicated on his restoration of *Coccosteus* ("Old Red," tab. 6, fig. 4) belong almost without exception to the lateral-line system. The figures given by Hugh Miller (Quart. Journ. Geol. Soc. 1859, p. 129, and "Footprints," 1st ed. fig. 11), in which he attempts to reduce the plates of the cephalic shield of *Coccosteus* to the same plan as that of the bones of the top of the head in the Cod, are much better, inasmuch as many of the true sutures are given; but it is also too plain that he also looked upon the superficial grooves as indicating the real boundaries of the plates which he considered as the homologues of the cranial roof-bones in osseous fishes. Pander's interpretation, although his figures give both sets of lines on the upper surface with considerable though not perfect accuracy, is correct only as regards the hinder part of the buckler, his reading of the anterior half being hopelessly wrong, and consequently his elaborate comparison with the arrangement in *Asterolepis* falls to the ground. By far the most correct restoration of the cranial shield of *Coccosteus* is that of Huxley,[1] in which he omits the superficial grooves altogether, and in which the only faults I can find are of omission, viz. the non-recognition of the median suture between the two central plates which he letters as "frontal," and of the *pair* of premaxillary bones on each side of that median bone in front, to which he applies the name "premaxilla."

In Pl. I. Fig. 2 I have given a sketch of the head of *Coccosteus decipiens*, Ag., the superficial grooves being given in dotted, the sutures in continuous lines, and as regards the names I have applied to the bony plates, I have thought it best to use as few as possible which might lead the reader to infer that I considered them the morphological equivalents of the cranial bones of ordinary fishes.

Posteriorly we have the trapezoidal *median occipital* plate (*m. o.*), flanked on each side by the triangular *external occipital* (*e. o.*). In front of these are the two *central* plates (*c.*), external to which and forming the antero-external margin of the buckler are three plates, *marginal* (*m.*), *post-orbital* (*pt. o.*), and *pre-orbital* (*p. o.*), the two latter forming the upper margin of the orbit. The two pre-orbitals come together in the middle line posteriorly only for a very short distance, in front of which they are separated by a narrow oval

[1] Dec. Geol. Survey, x. p. 30.

space open anteriorly, and in this space is lodged, first a small elliptical plate, the *posterior ethmoidal* (*p. e.*) and the median limb or stalk of the *anterior ethmoidal* (*a. e.*). This latter bone, the "premaxilla" of Huxley, is like a nail-head with a broken off stalk attached, the head forming the anterior point of the buckler, the stalk passing back between the pre-orbitals. On each side of it in front are the small nasal openings (*n.*), each being bounded externally by a small separate bone, the *premaxilla* (*p. mx.*). The orbit is bounded below by the "paddle-shaped" bone (*mx.* Fig. 3) representing the *maxilla*, which has a sort of resemblance to that in *Palæoniscus*, and to the posterior extremity of which is appended a small triangular plate (*j.*), the *jugal* or post-maxillary.

Turning now to *Homosteus*, we shall find that Hugh Miller's comparison of its cranial plates with those of *Coccosteus* is not so far amiss, of course, taking into account the faults of his reading of the buckler of the latter genus. In Fig. 1 I have sketched the configuration of the specimen of *Homosteus*, referred to by John Miller as having the dorsal plate *in situ*. Much of the bony substance having splintered off from the "specimen" itself, I have had a plaster impression taken from the "counterpart," which consequently reproduces the details of the original in a very much more perfect manner, and from this model the drawing has been taken. And I may add that every detail of the buckler here given is corroborated by another splendid specimen, also from the collection of John Miller, in which, however, the dorsal plate has got displaced to one side.

We find a wonderful correspondence in the arrangement of the bony plates, the differences appearing almost entirely due to the altered position of the eyes, and the assumption by the cranial shield of an antero-posteriorly elongated, instead of a broadly hexagonal figure.

The *median occipital* (*m. o.*), preserving its trapezoidal shape, has become much elongated, as have also the *external occipitals* (*e. o.*), while the *centrals* (*c.*) have become much smaller in proportion, and have come to take part in the inner boundary of the orbit, more, however, on the upper than on the under aspect; they are also in contact in front with the *posterior ethmoidal* (*pt. e.*), the hinder angle of which is inserted in a notch between their anterior extremities. The *marginal* (*m.*), also much elongated, is easily recognized; but it is now alongside of, instead of in front of, the external occipital, and the *post-orbital* (*pt. o.*) and *pre-orbital* (*p. o.*) have altered their relation to the orbit in a strange fashion. Separating internally, so as to allow the central to come into the boundary of that opening, they have thrown out processes which unite externally, and so in *Homosteus* the orbits come to be entirely enclosed *within* the buckler, instead of being *outside* it, as in *Coccosteus*. The last plate to be noticed is the *anterior ethmoidal* (*a. e.*), which occupies a position at the front of the snout exactly as in *Coccosteus*, but no trace is seen either of the small premaxillary, or of the nasal openings of that genus.

The lateral-line system of grooves is sparingly developed on the cranial shield of *Homosteus*. On each side the lateral groove passes along the external occipital and the marginal on to the post-orbital, where it divides into two branches, one of which passes outwards and forwards to the margin of the shield, while the other passes backwards and inwards to be lost near the middle of the central plate. If we compare this arrangement with that in *Coccosteus* (Fig. 2), we shall see that the plan is quite the same, although the extent of the groove-system is considerably diminished.

The facial bones of *Homosteus* are extremely difficult of determination, and I must frankly confess that I have come to no certain conclusions regarding them. In the specimen represented in Pl. I. Fig. 1 are three detached bones, A, B, and C, on each side of the anterior part of the cranium, by which B and C are also partly concealed, while on the right side the bone A is seen only in longitudinal section, having stood on edge to the bedding of the rock. When those bones are seen in connection with examples of the buckler, they alway occur in the same order, and isolated specimens of all of them are also in the collection of the Edinburgh Museum.

The bone A is broadest behind the middle, narrowest at each end, especially the anterior one. In the specimen here figured it is seen from the internal aspect, having apparently got turned over; but other specimens show that on the external aspect near the middle it had a patch of the usual tuberculation, with a short lateral-line system groove. This bone is figured by Hugh Miller as "lateral cerebral plate," but as many specimens in the collection show that its position was immediately below the edge of the antero-lateral portion of the buckler external to the orbit, the groove on its surface being a continuation of the transverse branch on the post-orbital, it is clearly the homologue of the paddle-shaped bone or *maxilla* in *Coccosteus* (Fig. 3). If this be the case then, we may assume that the bone B, following and parallel to it, is the mandible; but no traces of teeth can be found on either, or, indeed, on any bone which it is safe to refer to *Homosteus*. Like the Sturgeon it must have been edentulous.

The bone C is figured by Hugh Miller (Footprints, fig. 45*a*) as a clavical (here he meant what we now call post-clavicle); but, of course, such an interpretation founded on its superficial resemblance to the post-clavical of a modern Teleostean is here negatived by its position. Hugh Miller noticed the tuberculation of the outer side of one of its extremities, but in accordance with his theory of its position in the animal, he assumed this tuberculated portion to be its "head," or anterior extremity. The present specimen shows, however, that this extremity was posterior.

The last and crowning point of interest in the specimen represented in Pl. I. Fig. 1, is the exhibition of the dorsal cuirass *in situ*. Five plates are here seen, one median and two lateral, corresponding exactly to plates occupying a similar position in *Coccosteus*.

The central dorsal plate (*m. d.*) is so well known as Hugh Miller's

supposed "hyoid," that it requires no further description, beyond the remark that its resemblance to that of *Coccosteus*, except in its short broad shape and the want of the posterior elongated peak, must be evident at the first glance. It is here shown in position, its broad margin being directed forwards, and lying parallel to the posterior margin of the cranium, from which it is here separated by a narrow gap, its obtuse point being free and posterior. Its lateral margins overlap on each side two other bones, of which the anterior one (*a. d. l.*) was figured by Hugh Miller as "non-descript latero-hyoidal plate," he being well aware of its relation to the median bone, though, in accordance with his theory of the latter, he reversed its position. Its relation to the skull was, however, correctly represented by Pander ("Placodermen," tab. 8, fig. 2*a*.). It consists of two parts, one flattened above, and applied anteriorly to the outer part of the posterior margin of the skull, by which as well as by the median plate it is overlapped, and another, narrower, forming a right angle to the flattened portion and running forwards a little way along the posterior part of the outer margin of the cranial buckler; in the angle between the two parts is a socket for articulation with a corresponding projection of the postero-external angle of the external occipital. Naturally Hugh Miller found himself at a loss to account for the presence of this socket. Different as the two bones are in shape, it is impossible not to recognize in this bone the homologue of the *anterior dorso-lateral* in *Coccosteus* (Fig. 3), though here the socket and peg have changed their positions on the bones concerned.

Behind this anterior dorso-lateral there exists in the specimen figured in Pl. I. Fig. 1, another and much smaller plate (*p. d. l.*) on each side, which has not previously been noticed. It needs no reasoning to perceive at once that this is the *posterior dorso-lateral* of *Coccosteus* (*p. d. l.*, Fig. 3).

It is curious that no undoubted remains of a ventral body-carapace like that of *Coccosteus* have occurred in connection with *Homosteus*; but, at the same time, I might mention that the plate (Footprints, fig. 37) designated "palatal plate" by Hugh Miller, looks to me as if it might well be the anterior median ventral, so far as its shape is concerned, though its great size may be considered as somewhat against the supposition. At all events there is no evidence for referring it to the palate.

There are also several other bones figured by Hugh Miller and contained in the Edinburgh Museum, which from the way in which they occur, associated with other undoubted remains of *Homosteus*, clearly belong to the same fish, but whose position in the body I cannot speculate upon. These are the "operculum" (Footprints, 5th edition, fig. 39), the very curious bone (*ib.* fig. 43) spoken of by Hugh Miller, as "shoulder (*i.e.* coracoid?) plate"; his so-called "dermal bones" (*ib.* fig. 44). What the bones *c* and *e* in fig. 46 of the "Footprints" are I am also unable to determine.

But a number of the other remains figured in the "Footprints" as "*Asterolepis*" belong not to *Homosteus*, but to *Glyptolepis*

paucidens, Ag. sp. These are the scales (figs. 26 and 27), the mandibles (figs. 32, 33, and 36), the sections of teeth (figs. 34 and 35); the bone *d* (fig. 46), which I look upon as the lower end of the clavicle; and the interspinous piece (fig. 48), which Hugh Miller figured as the "ischium of *Asterolepis*." The latter is indeed a very curious bone, and it is not at all remarkable that the author of the "Footprints" should have sought to identify it with the basal bone of a ventral fin constructed in teleostean fashion. Knowing that such a pelvic fin-element could hardly have existed in either *Homosteus* or *Glyptolepis*, the bone was long a puzzle to me, until one day I observed a very similar bone supporting the distal set of interspinous bones of the second dorsal fin in a specimen of *Glyptolepis leptopterus*, also in the Hugh Miller Collection. A similar bone supporting three smaller interspinous elements was described and figured by Sir Philip Egerton in *Tristichopterus*.[1]

As regards the *species* of *Homosteus*, which has been under consideration, no specific name was given to it by Hugh Miller. By Morris[2] it was catalogued as the "*Asterolepis Asmusii*" of Agassiz, but I know not on what ground. Certainly I can find no resemblance between the sculpture of the surface of the plates of *A. Asmusii*, as given in Agassiz's figures, and that which characterizes the present fish in which the tubercles are small, sharply defined, with prominently stellate bases, and for the most part closely placed. Nor can it be identified with the species of *Homosteus* described by Asmuss from Dorpat, and so I would propose that for the future it be known as *Homosteus Milleri*.

EXPLANATION OF PLATE I.

(In all the figures the same letters refer to the same things.)

m. o. median occipital. *e. o.* external occipital.[3] *m.* marginal. *c.* central. *pt. o.* post-orbital. *p. o* pre-orbital. *pt. e.* posterior ethmoidal. *a. e.* anterior ethmoidal. *p. mx.* premaxillary. *n.* nasal opening. *m. d.* median dorsal. *a. d. l.* anterior dorso-lateral. *p. d. l.* posterior dorso-lateral. *a. l.* anterior lateral. *p. l.* posterior lateral. *i. l.* interlateral. *a. v. l.* anterior ventro-lateral. *p. v. l.* posterior ventro-lateral. *m. v.* posterior median ventral. A, B, C, three facial plates lying below the margin, anteriorly of the cranial shield of *Homosteus*.

FIG. 1. Sketch of a specimen of *Homosteus Milleri*, Traq., in the John Miller Collection, Museum of Science and Art, Edinburgh.

FIG. 2. Restoration of the top of the head in *Coccosteus decipiens*, Ag. The dotted lines indicate the distribution of the grooves of the lateral-line system.

FIG. 3. Sketch of a specimen of *Coccosteus minor*, H. Miller, from Thurso, the vertebral column omitted. Hugh Miller Collection.

II.—NOTE ON THE LOWER CAMBRIAN OF BETHESDA, NORTH WALES.

By Professor T. McKENNY HUGHES, M.A., F.G.S.

UNTIL quite lately no fossils had been found in the Lower Cambrian of Bethesda. Indeed we had almost given up the hope of obtaining any evidence of the life of the period represented by them, because of the great alteration in the character of the rock resulting from the severe mechanical action to which it had been

[1] Dec. Geol. Survey, vol. x. p. 52, plate 5. [2] Catalogue British Fossils, p. 318.
[3] On Plate I. in Fig. 2, for *p.e.* read *pt.e.* In Fig. 3, for *e.n.* read *e.o.*

subjected. The announcement that Mr. Robert Lloyd had discovered fossils in the uppermost slate beds of the Penrhyn Quarries was therefore received with great interest, which was increased when it was found that some of these were in a sufficiently perfect state for determination, and that they were referred by Dr. Woodward[1] to a new species of a well-known Lower Cambrian genus of Trilobite.

I have since found fragments of another smaller species in the same beds not far below the Bronllwyd grit.

The zeal of Mr. Robert Lloyd, to whom I am indebted for much valuable information, especially with reference to the subdivisions and measurements of the Penrhyn Slates, has recently been rewarded by the discovery of traces of fossils in the part of the quarry known as Sebastopol, some 1200 feet lower in the quarry than the *Conocoryphe viola* zone.

Unfortunately these specimens also are too obscure for determination. They appear to be the casts of the carapace of a Trilobite filled with radiating mineral matter, and are of somewhat the same size and outline as those of *Conocoryphe viola*.

I have thought it might be of interest to offer a few notes on the rocks seen in a traverse from a point a little west of Bethesda across the Penrhyn Quarries over Moel Perfedd to Cwmbual on the south, with a view to fixing the position of the only fossil zones yet known in that area, and pointing out the localities where it seems most probable that fossils may yet be found. The accompanying diagram section will facilitate reference :—

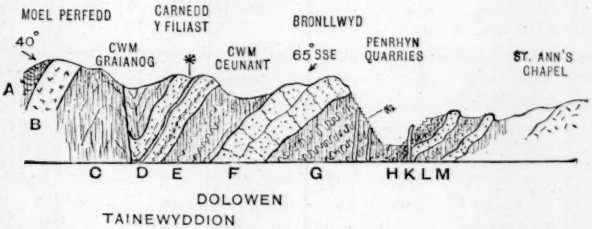


FIG. I.—Diagram Section N.N.W. and S.S.E. from St. Ann's Chapel to Moel Perfedd. Length of Section 2¼ miles. The cleavage is nearly vertical N.N.E. and S.S.W.

* Indicates horizons at which fossils have been found.

A. The slates south of Moel Perfedd are dark grey irregularly cleaved lumpy sandy beds which at one place dip at an angle of about 40° to the north, that is, towards the felspathic rock.

B. This felspathic rock behaves as an intrusive mass. It is not seen down the hill side to the bottom of the valley.

C. Black and grey slaty rock fills up the interval between Moel Perfedd and Carnedd Filiast. In this Cwm Graianog has its origin.

D. The grit of Carnedd Filiast is inclined at a high angle and runs down the north side of Cwm Graianog protruding in rough bosses near Tainewyddion. Here it is split up by finer beds upon the face of which *Cruziana semiplicata* is abundant.

[1] Quart. Journ. Geol. Soc. vol. xliv. pp. 74–78, pl. iv. 1888.

In the talus under the cliff above Tainewyddion I found several specimens of *Lingulella Davisii* in a grey or yellow flag similar to that which occurs subordinate to the Carnedd Filiast grit. We are here evidently in the Middle Lingula Flags, which is represented chiefly by massive coarse grit. When we wander south into the district west of Arenig, there are still beds of strong grit at this horizon, but they are thin and quite subordinate to the flags and slates. The shore line was further north, and therefore in that direction we may expect to find the rocks of this age either represented entirely by shore deposits or overlapped against the rising ground by the newer part of the series.

Below the Filiast grit we should search for Lower Lingula and Menevian, and we shall see that there are black slates about that horizon from which as yet no fossils have been recorded.

E. Between Carnedd Filiast and Bronllwyd there is a depression which, further east, forms the head of Cwm Ceunant. This hollow is due to the occurrence here of a soft pale grey and white irregularly cleaved sandy slate. It seems to be in the line of the softer rock which runs through the gap between Elidrfawr and the rocky hill which rises from Marchlyn Bach on the west. These slaty beds pass up into the sandstone and grit of Carnedd Filiast and down into the grit of Bronllwyd. A soft black slate is seen in this division above Pengareg; any part of this series might be expected to yield fossils and it is here we should search for Lower Lingula Flags and Menevian.

F. The grit of Bronllwyd, which comes next in descending order, and rests immediately upon the Penrhyn slate, consists chiefly of a quartz grit and conglomerate, containing fragments, generally about the size of a pea. It passes into banded grit and sandstone, with beds conspicuously mottled black and grey, the black being due to large mudpans, and included masses of shale pinched up in it, so as to occur very irregularly through what otherwise appear to be somewhat evenly lying beds. This proves that a considerable amount of deformation often takes place even in a massive grit. The alteration of a grit by cleavage into a schistose quartz rock is well known, but this fold and fault deformation is also clearly a common phenomenon.

The Bronllwyd grit is of great thickness, and rolls over rapidly to the south-east, a dip of 55° being observed in one place above the Penrhyn Quarry.

G. The Penrhyn slates, which next succeed in descending order, are wonderfully uniform in character throughout, but yet a close observation of those small differences which affect the quality of the slate has called attention to slight variations of texture, as well as the more marked difference of colour, and enable us to make out the fallowing subdivisions:—

a. Immediately below the Bronllwyd grit is a glossy light apple-green slate, somewhat like a hone stone in character. It is a useful slate, and was used for the roof of the new church at Bethesda. It has not been much worked, except in one quarry, known as Crimea,

a name much in people's minds at the time it was opened. In this quarry the new Trilobite, *Conocoryphe viola*, Woodward, was found by Mr. Lloyd. I verified its occurrence by finding several specimens myself. I have been able to add also another smaller species of Trilobite, but my specimens are too fragmentary for determination. There is also not uncommon in these beds a rounded pear-shaped body, with a granular texture and banded structure, perhaps some form of sponge. There are hardly any indications of bedding, except the regular roof of grit and the constant but less regularly occurring purple slates below. There are a few sandy lines and bands, which, however, can rarely be followed for more than a foot or so. The fossils appear on distorted bed faces, generally lying within 5° or 10° of the cleavage planes.

These beds are locally known as the Upper Green Slate, Maenty-gwyrdd uchaf, or Cerrig llwydion, and the estimated thickness is 120 feet.

The Upper Green Slate passes down into the next subdivision.

b. Purple Slate. The way in which this comes on shows that the colour does no go for much, as it occurs in a blotchy irregular manner, suggestive rather of local circumstances affecting the iron in the rock at any time subsequent to its deposition. It has often a silky texture; this character being seized upon by the workmen, who called it the Silky Vein, or Cerig Rhiwiog, as distinguishing it from the more sandy and irregular mass of slate below. It is of about the same thickness as the Upper Green Slate, viz. some 120 feet.

c. A coarser and less evenly cleaved rock which is called Bastard slate, and is said to be in thickness about 850 feet.

d. The old blue slate, so called first because it was one of the earliest quarried, and next because of its colour. The colour is, however, more green than what we should understand by blue when applied to a slate. This difference is lost in the Welsh name Careglas. It is in the upper part of this band that the traces of fossils have been recently found in the working known as Sebastopol, according to Mr. Lloyd's estimate, some 1200 feet lower than the Crimea quarry, or zone of *Conocoryphe viola*.

e. A bed of red gritty rock, known as Gwenithfaengoch, about 15 feet in thickness, separates this slate from

f. The Lower Purple Slate, Cerig Cochion, which attains a thickness of 300 feet, and passes down through

g. About 240 feet of veined slate, known as Cerig gleision gwythienog, into

h. The Lower Green Slate, Gwyrdd isaf, in which there is some 300 feet of workable slate.

H. Greenish sandy beds, with included fragments of older rock, are just touched at the bottom of the quarry. These are probably the top of the passage beds into the schistose fragmental rock, which is associated with

K. The cleaved grit and conglomerate, seen near the bridge, south of Bethesda.

L. Below these come the slates of the Tramway cutting, to be more fully described in illustration of the chief point of this communication, viz. the nature of the deformations which have taken place in the Penrhyn slates, and their bearing upon the manner of occurrence of fossils in different parts of the series.

M. To the north of these the St. Anns Grit crops out. It was touched in breaking ground for the new brickworks near St. Anns, and was quarried for use in some of the buildings connected with them. It contains numerous and conspicuous grains of hyaline quartz, as well as of pink quartz and jasper, in this resembling the Cambrian grits of the Bangor-Carnarvon area.

Such is the succession of rocks seen south of Bethesda. There is no proof here of a repetition by complete inversion of any large portion—though the rocks have been much crushed up in detail.

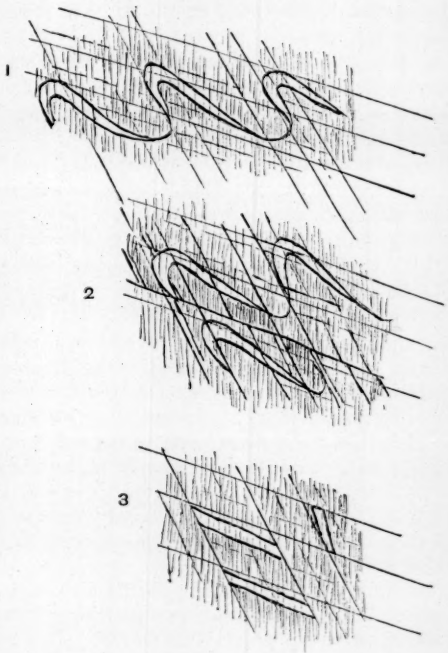
One of the various difficult questions raised by the examination of this district is, What were the conditions which favoured the preservation of fossils only here and there in this great thickness of rock? The first and most obvious reason which suggested itself was that the great unyielding mass of the Bronllwyd Grit, immediately below which the fossils occurred, saved the underlying bed from the severity of the crush, and that the finer rock therefore split along bedding planes parallel to the base of the grit. An examination of the section, however, soon showed that this explanation would not hold: for the fine green rock is strongly cleaved right up to the base of the grit, and the grit itself has evidently suffered much in the crush, as shown by the squeezed-up mudpans and the contortions of the finer parts. Moreover, if the occurrence of fossils 1200 feet lower down in the quarry and far from any unyielding mass of grit be verified, we must seek some other reason for the exceptional preservation of such traces.

When in the quarry we endeavour to seek an explanation, we notice first that the fossils do not occur in the planes of bedding as inferred from the lie of the large consecutive masses of rock of different lithological character. Yet the fossils can never have been of such rigidity as to have been thrust into approximate coincidence with the planes of cleavage during the crush which produced it. Further we observe that there are no bands or lines suggestive of stratification running parallel to the dip inferred from the alternating beds of grits and slates. Any such bands and lines are irregular, interrupted, of small extent, and at all angles to the constant cleavage.

In rocks of such a uniform character as the Penrhyn Slates the relative displacement of parts is never easy of detection. If, however, we follow them to where some of the beds are picked out by differences of colour and texture, so that we can disentangle the complications, we get a clue to the processes by which the rock has been reduced to its present state, and an explanation of the irregular manner of occurrence of the fossils. In the Tramway cutting for instance, between the St. Ann's Road and the Quarries, we see that the bands which here mark bedding are twisted, drawn out, doubled

back, interrupted, and repeated, in every variety of fold and break—of which examples are given in the subjoined woodcut, Fig. II.

Fig. II.



The selection shows three stages of the same class of movements, where the folds are more conspicuous in the first and the faults in the last, so that in it portions of the folds are faulted out of the field of view altogether. This is not cleavage, nor necessarily connected with cleavage, and on this distinction I would lay particular stress. Many rocks, such as the gnarled series of Anglesea and parts of the Devonian of Devonshire, show the fault and fold structure with inconspicuous cleavage. This is the action which produces schistosity in all sorts of rock, modified, of course, by its original character, whether, for instance, it is a soft rock with subordinate hard beds, or a somewhat uniform mass with veins. The essential character of the fold and fault structure being that there is a relative displacement of considerable portions of the mass, producing what I have elsewhere called a universal slickenside. The essential character of cleavage being that there is no such displacement of considerable portions of the rock, but only a molecular rearrangement producing a tendency to split along an indefinite number of parallel planes.

Cleavage may affect a rock in which the bedding planes are not

contorted, so that fossils are often found along an even line on the edges of the cleavage planes.

Cleavage may be superinduced upon a rock already affected by fault and fold structure, especially in a rock of a fine and homogeneous character, and this is what seems to have taken place in the case of the Penrhyn Slates.

Doubts as to the nature of cleavage may often be traced to the want of a clear distinction between these two superinduced structures—the molecular rearrangement due to cleavage and the kneading of the mass with *fault and fold schism.*

Why pressure should in one case crumple up the beds and in another make them yield as a plastic body, is a separate question probably capable of receiving different correct answers in different cases. What we are aiming at now is the establishment of the fact that there is this two-fold action, and resulting different structure, and the application of it to the explanation of some stratigraphical difficulties.

In these lower Penrhyn Slates the direction of displacement of well-marked beds is not even generally coincident with cleavage. We see here evidence that there is not only a thickening of homogeneous masses by molecular movement approximately at right angles to the direction of pressure as indicated by the cleavage, but also a folding and crumpling of the beds, so that one layer is repeated three or four times in the same vertical section.

Thus we get a suggestion of the reason why fossils may be found only here and there in a rock-mass which appears to be throughout of a similar character and to have been subjected to similar conditions. The cleavage often leaves the fossils on planes along which the rock will not split, at the same time distorting them beyond the possibility of recognition in small fragments. But when the rock has been crumpled and folded previous to or coincidently with the cleavage, some specimens here and there will lie on faces which have suffered less deformation or coincide with easy divisional planes.

The great rock-masses near Bethesda roll away in great undulations, having a general dip to the south and east; but subordinate masses are puckered, behaving under this enormous pressure as if plastic, the greater surface extension being compensated by diminished thickness and *vice versâ.*

Ramsay[1] pointed out that the vertical extent of some of these beds was probably greatly in excess of their original thickness.

This kind of thing is, of course, most likely to occur in such cases as that which we are considering, where the newer beds abut against an axis of older rocks which have been already squeezed and shrunk beyond the possibility of much further compression, just as in a crowd the man who is jammed against the wall or post gets most hurt.

We further notice that along the old Archæan axes two things happen which account for a very rapid disappearance of beds which are seen to be of great thickness in a closely adjoining area.

[1] Mem. Geol. Survey, vol. iii. pp. 190–196.

There is first the accumulation in the hollows and an overlap of the later over the younger part of the same series as the successive deposits creep up the flanks of the submerged land.

And, secondly, there is the exaggeration of the thickness of the mud accumulated in the hollows when pressure supervenes and squeezes it up against the base of the cliffs and steep mountain chains of the ancient submerged land.

Thus the manner of occurrence of the fossils in the Penrhyn quarry throws some additional light on the processes which have modified the older rocks even to the exaggeration of thickness.

There is not such a great difference in the thickness of the lowest part of the series at Bethesda and Bangor, and even that difference can be much reduced by allowing for the increase in the apparent thickness of the Penrhyn slates by squeeze.

The still greater missing series at Carnarvon may be accounted for by the overlap of higher over lower Cambrian against an important sea-bordering Archæan mountain range. The lowest Cambrian beds at Carnarvon were thus a higher and newer part of the system, and being nearer the tops of the mountain ridges escaped the great crush that caught the older and deeper beds thrown down nearer the base of the ancient range.

III.—Notes on the Physics of Metamorphism.

By Alfred Harker, M.A., F.G.S.,
Fellow of St. John's College, Cambridge.

THE problem of the metamorphism of rock-masses is one in which increased study has not led to unanimity of opinion. The literature of the recent Geological Congress in London suffices to remind us, how widely divergent are the conclusions to which various geologists have been led by researches in the field. Since, then, the *a posteriori* line gives such very different results in different hands, it may be worth while to revert for a moment to the deductive method, and try to trace the consequences, in this connexion, of admitted physical principles.

Since some definition of our subject is necessary, we will, for the present purpose, group together under the name metamorphism all processes which result in a partial or complete crystallization or re-crystallization of solid masses of rocks. Such changes are usually effected through chemical re-arrangements, and are often attended by the development or creation of special structural planes in the rock-masses. Those processes which do not appear to demand either a high temperature or a high pressure, such as the conversion of sandstone into quartzite by deposition of interstitial quartz, although logically included here, will not be discussed. We may conveniently distinguish them as *hydro-metamorphism*, recognizing the important part played by water in changes of this kind.

The geological manuals lay down a fundamental distinction between *contact-* and *regional*-metamorphism; but from our present starting-point we arrive at a somewhat different division. It is

indeed evident that what is essential to contact-metamorphism is not the proximity of an eruptive mass, but simply an elevation of temperature; and, so far as chemical and mineralogical changes are concerned, it is immaterial whether the heat be conducted from some neighbouring source or generated in situ by mechanical or other means. It appears, again, from the writings of many geologists who invoke the operation of mechanical force in explanation of metamorphism, that they require nothing of that agent beyond the generation of heat by the crushing of the rocks operated upon. A theory based on these lines fails to show any cause for difference between the results of dynamical and of contact-metamorphism. That differences of kind exist, is, however, generally admitted. Certain minerals, such as andalusite, tourmaline, garnet, and idocrase, are known to be especially associated with the alteration of stratified rocks at high temperatures. On the other hand, there are changes, such as the amphibolisation of pyroxene, the saussuritisation of plagioclase, the conversion of potash-felspar into white mica and quartz, and the production of sphene at the expense of titaniferous iron ores, which are characteristic of altered rocks showing clear evidence of mechanical stress. These two phases of metamorphism by no means exhaust the possibilities, but they apparently compel us at the outset to recognize as distinct from one another a *thermo-* and a *dynamo-metamorphism*, the pressure in the latter case operating not through the medium of heat generated, but immediately. In short, we must admit the *direct* correlation between mechanical and chemical energy, to which experimental results unmistakably point.

While allowing the potency of pressure as a factor in geological transformations, many writers seem reluctant to admit it to a rank co-ordinate with temperature, as one of the conditions governing all chemical processes. They quote the experiments of Mallet, but overlook those of Cailletet and Spring. But if the chemist can, for the most, neglect in practice the effects of variations of pressure on solid bodies, it is only because the range of pressure in his experiments is comparatively small: the laboratory of nature knows no such restrictions. In parts of the earth's crust with which geological research is concerned, there must be enormous pressure, as well as extreme temperature; and these two, though often locally coinciding, must be physically independent. For rough purposes we may separate four sets of conditions, which may exist in various places, and which may be expected to govern the atomic forces in different manners, giving rise in their several provinces to different chemical combinations:

(i). Low temperature and low pressure (*hydro-metamorphism*).
(ii). High temperature and low pressure (*thermo-metamorphism*).
(iii). Low temperature and high pressure (*dynamo-metamorphism*).
(iv). High temperature and high pressure (*plutono-metamorphism*).

The first, in the widest sense, will embrace various chemical changes which go on chiefly near the surface of the earth. The second will be typically represented by 'contact-metamorphism,' but will also include cases in which the crushing of rocks under a

moderate pressure gives rise to the generation of heat sufficient to produce a considerable rise of temperature. The third set of conditions will be best exemplified when pressure acts on a rock-mass not rigid enough to offer great resistance to crushing. A good illustration of its effects is seen in satiny slates or *phyllades*, such as those of Fumay, and perhaps of Llanberis and Michigan. These rocks, distinguished from mere clay-slates, must in some cases be classed as highly metamorphic. They appear to consist largely of authigenic minerals, and their highly-developed cleavage-structure is in fact a micro-foliation.

By applying to various districts of altered rocks this distinction of thermo- and dynamo-metamorphism, that is, by considering the proximate instead of the mediate causes of the chemical transformations, we may possibly find a clue to some apparent anomalies. One of these is the interpolation of thermo-metamorphic rocks in the midst of a region of dynamo-metamorphism. Such are the puzzling *cornéites* (composed of biotite and quartz), the garnetiferous and other special rocks of the Remagne and Bastogne district in the Belgian Ardenne. Their peculiarity seems readily to connect itself with the facts that they occur in the cores of anticlinal folds, where they must have been crushed upon themselves, and that the rocks thus affected, unlike their neighbours, are hard beds which would offer resistance to the deformation, and so give rise to the generation of heat.

It is not to be expected, however, that the varied mineralogical phenomena of a great metamorphic region will in general divide themselves into those due to high temperature and those due to high pressure. We have still to reckon with the case of great heat produced by the crushing of large masses of hard rocks under a pressure itself sufficient to modify materially the chemical affinities. The results produced by the superposition of thermo- and dynamo-metamorphism must be very complex: but we have no reason to suppose that these are comparable in any special way with the effects of a very high temperature and an intense pressure operating simultaneously. Indeed we must recognize in this latter a problem to which we can bring no direct experimental knowledge. Rocks which have been subjected to such conditions may presumably assimilate in some respects to those solidified from fusion under similar circumstances, although we should expect differences of textural and structural characters between the two. Failing a better name, we may accordingly use the term *plutono-metamorphism* to describe the profound changes in rocks implied in the joint influence of very elevated temperature and enormous pressure.

Experiments in the artificial reproduction of minerals have led geologists to lay stress on the presence of water during the transformation of rocks. This question does not touch the fourfold division suggested above. The temperature and the pressure must in general[1] completely define the conditions of the chemical pro-

[1] The exceptions being fusion and solidification, which cannot fairly be classed with metamorphism.

cesses involved (local solution, crystallization, etc., being included as chemical changes): water, if present, is one of the substances in which the recombinations are induced; in other words, a part of the rock. In pure thermo-metamorphism it is probable that the expulsion of contained water is the first effect of the rise of temperature, and observations show that this is true even of the liquid enclosed in the minute pores of crystals. High pressure acting upon rocks containing water will, as appears from theory and experiment, assist solution, but retard the complementary process of crystallization from solution. An important case will be that of a heterogeneous rock-mass in which the pressure varies from point to point. Here the solution of minerals at the points of maximum pressure, and their deposition where the pressure is least, must be a factor of great potency in the transformation of the rocks. Indeed this action, first pointed out by Sorby, may have a very important application to the separation of the several constituent minerals, and their segregation into lenticular streaks, which mark a common type of crystalline schists.

As is indicated by the last suggestion, the structural cannot be strictly separated from the chemical effects of pressure. Such separate consideration is to some extent possible only with comparatively soft rocks, which do not offer great resistance to deformation. In such cases it is useful to remember that a pressure in a definite direction is mathematically equivalent to a uniform pressure together with certain shearing stresses. Of these the former tends to produce a change of volume without change of shape, *i.e.* a uniform compression, the latter a change of shape without change of volume, *i.e.* a shear. Both these changes involve an expenditure of mechanical energy, but the energy expended in shearing will be small in the case of a soft rock. The term *shear* is here used to describe a continuous deformation, not a disruption. This seems a legitimate adaptation of the mathematical word, although since rocks are heterogeneous bodies, their "shearing" presents only a geometrical, not a physical, analogy to the shearing of elastic and viscous substances. In this useful sense the expression was introduced into geological literature by Mr. Fisher only four years ago, and it is to be regretted that it has been so soon perverted by those who apply it to discontinuous sliding or faulting.

We frequently find it stated, or assumed, that when structures such as cleavage or foliation are set up in a rock-mass by shearing, they are parallel to the direction of shearing; although, as has often been pointed out, they must really be perpendicular to the maximum linear compression. In other words, these structural planes are parallel to the chief diametral plane of the strain-ellipsoid, while the shearing-planes, if they remain constant in direction, are parallel to cyclic sections of the ellipsoid. Only for a large amount of shearing will the shearing-planes and the induced structural-planes become nearly parallel.

In a rock of considerable rigidity, shearing as well as compression involves the expenditure of mechanical energy, which must be

converted into heat or chemical energy or both, and so contribute to the chemical part of the metamorphism.

There is another case which must be to a certain extent realized by some rocks, and which we may picture as that of a mass consisting of grains individually rigid, but capable of sliding upon one another. This is the "granular medium" investigated by Professor O. Reynolds.[1] Here a pure shear is impossible, since any change of shape in the whole, effected by rearrangement among the grains, involves a change of total bulk. If such a mass has already been "packed" into a state of minimum volume (not necessarily the least possible volume), any deformation will increase its bulk, and so will be resisted by the pressure. Such a condition could be permanently relieved only by chemical action, beginning perhaps by the solution of the grains at their points of contact. It appears too that the intercalation among more yielding materials of a granular rock, which becomes in places "packed" to a minimum volume, will often determine internal disruption and faulting of the mass.

The relation between foliation and the banded or gneissic structure is a question which need only be referred to briefly. When the latter is produced by the same prime agent as the former, as for example in the manner described by Mr. Teall,[2] the two structures will necessarily be parallel to one another. But when foliation is set up by dynamical agency in rock-masses possessing a previous banded structure, whether from stratification, or earlier metamorphism, or any other cause, the former will not of necessity be parallel to the latter, although it will tend to become so with increasing deformation. Numerous examples of foliation oblique to gneissic structure have been described and figured.[3] For the sake of clearness, it does not seem advisable to name this peculiarity "double foliation." If we use the term foliation strictly with reference to the intimate structure of the rock, and not to alternations of different petrological types, a rock-mass cannot present two foliations in the same place: the second will destroy the first as a direction of true schistosity. The same is true of slaty cleavage, notwithstanding various statements to the contrary. I have examined numerous examples of the local phenomenon styled "double cleavage" in the Ardennes, and in all cases resolved the second set of structural planes into a false (or *ausweichungs*-)cleavage, consisting in a succession of minute folds or faults of the kind figured by Heim, Reusch, and others.[4] The "cross-cleavage" of Wales and the Lake District appears to be merely a fine jointing.

In conclusion, it may be well to remark that the analysis of internal forces into uniform pressure and shearing stresses is quite general. Such ideas as torsion or wrench on a screw do not import

[1] Phil. Mag. ser. 5, vol. xx. p. 469, 1885.

[2] Geol. Mag. 1887, p. 484.

[3] Q.J.G.S. vol. xliv. p. 398; 1888: Reusch, *Krystallinischen Schiefer*, pp. 74 and 115; 1883.

[4] *Mecanismus der Gebirgsbildung*, plate xv. figs. 8 and 11; 1878: *Krystallinischen Schiefer*, p. 51; 1883: *Bömmeloen og Karmöen*, p. 196; 1888: Report Brit. Assoc. for 1885, pp. 838 and 840.

anything new with respect to the conditions of rock-transformation. They express usefully theories as to the distribution of mechanical stress and its induced metamorphism, but do not give rise to any new *kind* of metamorphic processes.

IV.—On the Ballantrae Rocks of South Scotland and their Place in the Upland Sequence.

By Prof. Charles Lapworth, LLD., F.R.S., F.G.S.

Part I.—The Ballantrae Rocks.

ON the extreme north-west flank of the Lower Palæozoic region of the Southern Uplands of Scotland there occurs a remarkable coastal area of stratified, igneous and altered rocks, known to geologists as the "Ballantrae Rocks," from the little fishing town of Ballantrae, which is built upon them. They range along the shores of the Firth of Clyde for a distance of about 12 miles, and are well displayed in section in a series of rugged cliffs cut through by the picturesque coast road between Ballantrae and Girvan. The area they occupy nowhere exceeds five miles in width, and is limited inland by the smoother regions floored by the barren greywackés of the Uplands and the fossiliferous strata of the Girvan district, but this inland boundary is everywhere curiously broken and irregular.

The rocks occurring within the limits of the Ballantrae district consist of—(*a*) conglomerates, limestones, shales, quartzose flagstones, and volcanic grits and tuffs; (*b*) broad sheets of serpentine, porphyrite, and various crystalline rocks; and (*c*) irregular masses of gabbro, diabase, and dolerite. Of the mutual relationships and true systematic position of these rocks, very diverse views have been advocated by geologists. Some of the unaltered limestones within the Ballantrae area were proved by Mr. Carrick Moore,[1] as early as 1848, to contain the same fossils as the well-known limestones of the Stinchar valley (and consequently to be of Llandeilo-Bala age). Since that date a few additional fossils have been recorded from the rocks of the area,[2] but these have all been procured from the same well-marked limestone zone.

The presence of these Llandeilo-Bala fossils in the limestones of the Ballantrae district has been very naturally held by most geologists as fixing generally the geological date of the associated stratified, igneous, and altered rocks. By some this deduction has been carried out fully, and the whole of the Ballantrae rocks have been described as Bala beds in various stages of metamorphism.[3] By others, however, while the Ballantrae rocks were placed, as a whole, with the Stinchar Limestones at the base of the fossiliferous Girvan sequence, some of their crystalline members were regarded as of igneous and eruptive origin.[4] Finally, others, who were aware of the faulted and convoluted character of the region, have suggested that some of its included rocks may be even of Pre-Cambrian age.[5]

By myself the Ballantrae rocks have been looked upon as a

[1] Q.J.G.S. 1849, vol. v. pp. 7-17. [2] Explan. Geol. Surv. Scot. Sheet vii., p. 9.
[3] J. Geikie, Q.J.G.S. 1866, vol. xxii. p. 513-534.
[4] Murchison, Siluria. 5th ed. p. 155, note.
[5] Hicks, Q.J.G.S. 1882, vol. xxxviii. p. 665.

complex formed of—(*a*) the Stinchar limestone and conglomerate series; (*b*) a stratiform series of sedimentary and volcanic rocks of much earlier date; and (*c*) intruded igneous masses of subsequent but unknown geological age. When the first and last of these sections had been satisfactorily eliminated, I believed that the remainder—or Ballantrae series proper—would prove to be of higher antiquity than any of the fossiliferous strata hitherto recognized in the Southern Uplands.[1]

In my paper[2] upon the Girvan succession the rocks of the Ballantrae complex are thus referred to:—"These Girvan rocks (Llandeilo-Bala to Wenlock) appear to repose at their base upon the generally older igneous and altered rocks of Ballantrae. The Ballantrae rocks have as yet been too imperfectly studied to allow us to hazard any conclusion respecting their true geological age. That many of the rocks grouped together under this title are of far greater antiquity than the basement beds of the Girvan succession may be regarded as established by the fact that fragments of the Ballantrae rocks occur in the Kirkland or Purple conglomerate at the base of the Girvan succession. These (their) Pre-Girvan traps and ashes must either represent the Arenig and Llandeilo (Lower) volcanic rocks of Wales and Cumberland, or must be of more ancient date. On the other hand, rocks which are unquestionably of true Girvan age occur at many localities within the typical Ballantrae region itself, while the patches of altered or so-called Ballantrae rocks (of that memoir) found outside that area, as at Shallock Hill, Laggan Hill, and elsewhere, almost certainly include some greatly altered Girvan rocks."

The time at my disposal for working out the main object of my Girvan paper—namely, the determination of the natural order of succession among the fossiliferous rocks of the Girvan district—did not admit of my devoting more attention to the rocks of the Ballantrae complex than was sufficient to establish their inferiority as a whole to the fossiliferous Girvan series. Hence all the rocks (sedimentary, igneous, and altered alike), whose position and characters showed that they formed a part of the heterogeneous Ballantrae complex, were provisionally grouped in that paper under the title of "Ballantrae rocks." It was perfectly clear however that before the Girvan stratigraphy should be regarded as even fairly complete it would be absolutely necessary to—(1) study in greater detail the rocks of the altered or so-called "Ballantrae patches" within the limits of the Girvan area, and separate off their included post-Girvan igneous intrusions and the Girvan rocks these had hardened and altered, from the truly older stratiform rocks of pre-Girvan date; and (2), to establish on the same palæontological evidences as those relied upon in determining the systematic position of the various members of the Girvan succession, the pre-Girvan age of those members of the Ballantrae complex which were held by myself to be of higher antiquity than the basement beds of the (Upper Llandeilo) Girvan succession.

[1] Compare Lapworth, Q.J.G.S. 1878, p. 341; *ibid.* 1882, p. 663; and Trans. Geol. Soc. Glasgow, 1878, p. 83.

[2] Lapworth, Q.J.G.S. 1882, vol. xxxviii. p. 663.

With these especial aims I paid a visit to the Girvan district in 1885, and was then able to satisfy myself upon the following points:—

1. The diabases, syenites, gabbros and serpentines occurring in the altered patches within the limits of the Girvan district proper are many (if not all) of post-Girvan (post-Silurian ?) age. They occasionally traverse, and usually harden and alter, such of the Lower Girvan rocks as they are locally associated with (as at Shallock Hill, Meadowhead, Byne Hill, Laggan Hill, Craighead Hill, and the slopes of the valley of the Stinchar); so that (exception being made of some of the strata of the last three areas named) the igneous and altered rocks of these patches have no claim to be ranked as of Ballantrae age. These post-Girvan igneous rocks have intruded themselves mainly in sheets along the many anticlinal arches into which the Girvan rocks are thrown, either between the Girvan rocks and the Ballantrae rocks proper, or among the limestones and conglomerates, etc., which make up the basal members (Barr or Stinchar Series) of the Girvan succession.

2. Similar igneous rocks (apparently of corresponding age) are met with in mass within the limits of the Ballantrae region itself, and have been equally operative in hardening and altering the enveloping strata. But in addition to these post-Girvan masses and the infolded Girvan (Stinchar) limestones and conglomerates of the region already referred to, the Ballantrae rock complex actually includes great thicknesses of stratiform rock—volcanic (contemporaneous), sedimentary, altered and unaltered; some of the last of which are distinctly of pre-Girvan date (and consequently of higher antiquity than any fossiliferous stratum yet recognized in the Southern Uplands)—for they contain locally a well-marked Graptolitic fauna of *Arenig* age.

The Arenig fossils occur in certain hardened black shales on the sea-shore at Bennane Head, about the centre of the Ballantrae area. These shales are associated with siliceous and felspathic grits and flagstones, purple shales, conglomerates and various igneous and altered rocks. Similar black shales occur near Lendalfoot, on the north-western slopes of Craighead Hill and elsewhere, but hitherto they have afforded no determinable fossils.

The recognizable forms collected by myself from the Bennane shales include:

Phyllograptus typus, Hall.
Tetragraptus quadribrachiatus, Hall.
,, *bryonoides*, Hall.
,, *fruticosus*, Hall.
,, *Biysbyi* (*caduceus*) ?, Hall.
Didymograptus extensus, Hall.
,, *bifidus*, Hall.
Caryocaris Wrightii, Salter.
Associated with forms of *Dictyonema*, *Lingula* and *Obolella*.

It is almost unnecessary perhaps to point out that we have here a Scottish representative of the well-marked fauna of the middle zones of the Arenig Quebec or first Ordovician fauna of South Britain, Northern Europe, and Eastern America. Not only is the general facies of the fauna of the well-known Arenig Point Levis, or Skiddaw type, but the Bennane forms occur—as will be apparent from a study of the following table—always in the same association.

TABLE SHOWING THE RANGE OF THE BALLANTRAE GRAPTOLITHINA.

SPECIES.	Skiddaw Slates.[1]	Arenig of St. Davids.[2]	Point Levis[3] Quebec Group.	Quebec Group. Newfoundland.[4]	Phyllograptus Schists. Sweden.[5]	Phyllograptus Schists. Norway.[6]	Australia.[7]
Phyllograptus typus, Hall	x	...	x	x	x	x	x
Tetragraptus bryonoides, H.	x	x	x	x	x	x	x
„ *quadribrachiatus*, H. ..	x	x	x	x	x	x	x
„ *fruticosus*, Hall	x	...	x	x	x	x	x
„ *Bigsbyi*, Hall	x	...	x	x	x	x	
Didymograptus extensus H.	...	x	x	x	x	x	
„ *bifidus*, H., *Murchisoni*, Beck.	x	x	x	x	...	x	
Caryocaris Wrightii, Salt.	x						

We have therefore in the foregoing facts a complete palæontological demonstration of the theory that the local series of rocks to which the title of Ballantrae Series or "Ballantrae rocks" has been applied, is in reality a complex of stratified, altered, and igneous rocks of very different geological ages: Arenig, Llandeilo, and post-Ordovician: the common facies of the pseudo-series being mainly the result of the common interfolding, alteration, and intrusion its rocks have undergone. The development of the natural order, inter-relationships and mode of alteration of this complex has yet to be worked out, and can only be satisfactorily accomplished by a mapping of the entire district, zone by zone, and band by band. When that work has been completed, it is by no means unlikely that fossiliferous zones of a yet higher antiquity may be detected; and that here it will be shown that, as elsewhere, the most extreme views held regarding the collective rock series may each have contained a certain proportion of the actual truth.

Although the simple fact of this discovery of an Arenig fauna in the Ballantrae rocks has long been made known,[8] I have hitherto withheld the foregoing details, because of their vital bearing upon the general question of the true sequence of the Lower Palæozoic rocks of the Scottish Uplands. The present, however, appears to be the most natural time for their publication. The epoch-making memoir by Messrs. Peach and Horne on the structure of the N.W. Highlands in the Quarterly Journal of the Geological Society for August, 1888, p. 378, has given the finishing-stroke in Britain to the antiquated ideas of the reliability of apparent stratigraphy in areas subjected

[1] Nicholson, 1872, Brit. Mon. Grapt. p. 97, etc.
[2] Hopkinson and Lapworth, Q.J.G.S. 1875, p. 635.
[3] Hall, Grapt. Quebec, 1865, pp. 56-57.
[4] Coll Canadian Geol. Survey.
[5] Tullberg, Skånes Grapt. pt. i. 1882, p. 22, etc.
[6] Brögger, Die Silurischen Etagen 2 und 3, 1882, pp. 38-41.
[7] Lapworth, Geol. Dist. Rhabdophora, 1879, p. 23.
[8] Jukes-Browne, Historical Geology, 1886, p. 98.

to intense lateral pressure. The conscientious and detailed paper by Messrs. Marr and Nicholson[1] on the Stockdale Shales of the Lake District, in the November Number of the same publication, has brought home to British geologists, in an equally convincing manner, the untenability of the views of those few surviving stratigraphists who still hesitate to acknowledge the paramount value of the Graptolites in the elucidation of complicated questions of stratigraphy and correlation among the Lower Palæozoic rocks.

In these two typical papers the *zonal* and detailed method of stratigraphy, as opposed to the *regional* and generalized method, has been consistently followed throughout, and it is to the adoption of this method I believe that they owe their reliability and their success. This zonal method, which has always been employed by myself in my work among the convoluted rocks of the Scottish Uplands, has thus quietly entered upon what may be regarded as the accepted or orthodox stage. With the new interest springing up among British geologists respecting the natural sequence and the proper classification of the Lower Palæozoic rocks, it may be regarded as certain that the complicated region of the Scottish Uplands will now be studied in fuller detail by geologists acquainted with the new methods, and that such differences of opinion as still exist among geologists respecting these rocks will soon find their natural solution and harmony, as in the cases of the Lake District and the N.W. Highlands, in a careful and detailed investigation of all the actual facts.

(To be concluded.)

V.—On a New Species of the Genus *Protaster* (*P. brisingoides*), from the Upper Silurian of Victoria, Australia.

By J. Walter Gregory, F.G.S., F.Z.S.,
of the British Museum (Natural History).

So little is as yet known of the Palæozoic Ophiuroidea, that the discovery of some specimens that represent a new species of *Protaster* in the Upper Silurian rocks of Victoria is of interest. Some of the specimens were forwarded to Dr. Woodward by Mr. Frederick McKnight, of 60, Hawke Street, West, Melbourne, Victoria, some time ago, but they were too fragmentary to be of much service; several better examples having been received from the same source, Dr. Woodward has kindly entrusted them to me for description.

Protaster brisingoides, n.sp.

Disk obscurely indicated: apparently of medium size and pentagonal in shape, each face being concave owing to the disk extending slightly along the arms. It is seen only in one specimen, and in this but faintly.

The arms are at least twice as long as the diameter of the disk, and probably considerably more, the full length not being known.

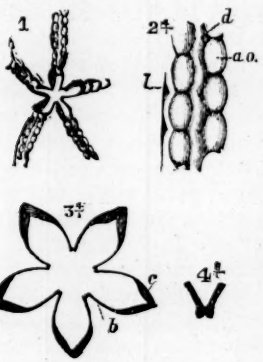
The mouth-frames are homologous with the ambulacral ossicles of

[1] Quart. Journ. Geol. Soc. (read May 9), 1888, vol. xliv.

the arms; they are about three times as long as broad and somewhat spindle-shaped, being more bulging in the middle than in *P. leptosoma*, which is the nearest ally of this species; the margins are entire and not notched as in that species. The adambulacral elements in the "oral pentagons" probably represent the jaw and jaw-plate; the former is long and narrow, about four times as long as broad, and slightly curved at the inner end (Fig. 3, *b*); the jaw-plate, which unites the jaw to that of the adjoining radius, is short and thick; its inner surface is concave, as the two free corners extend somewhat towards the centre of the disk (Fig. 4, *c*). Neither buccal nor dental papillæ nor teeth are shown.

Each arm consists of a series of pairs of ambulacral ossicles (Fig. 2, *ao*) and adambulacral plates (Fig. 2, *l*) on each side of a median ridge, seen on the abactinal surface (Fig. 2, *d*): the first apparently represent the unfused halves of the ambulacral or vertebral ossicles of Ophiuroids; the second, the lateral or adambulacral shields: the nature of the median ridge is doubtful; it may possibly represent upgrowths from the ambulacral ossicles comparable to those in *Brisinga*, or it may have some connection with the dorsal shields, which are not otherwise indicated. Seen from the abactinal aspect, the ambulacral ossicles appear thick and bluntly oval, with the longer axis in the direction of the arm, and placed alternately in the concavities of the sinuous median ridge; they are distinctly

Dimensions.—Diameter of disk	12 mm.
Diameter to the extremities of the oral pentagons ...	7 mm.
Width of arm	2 mm.
Length of ambulacral ossicles	1 mm.



Explanation of the Figures.

Fig. 1. Specimen of *Protaster brisingoides*, abactinal aspect; nat size.[1] Fig. 2. Part of an arm from the same specimen, that which is uppermost in Fig. 1; *d*. median ridge; *a o* ambulacral ossicle, *l*. adambulacral plate: ×4 diam. Fig. 3. The oral apparatus from another specimen in which the disk is not shown; *b*. jaw, *c*. mouth-frame; ×4 diam. Fig. 4. A jaw-plate and distal ends of a pair of jaws; ×8 diam.

[1] The faint indication of a disk is not shown in the figure, but can be detected in one or two of the interradii.

alternate in the arms, but in the disk, which includes the first three pairs, they are merely subalternate. The ambulacral ossicles are much thicker than those of other species of *Protaster*, and they are consequently less numerous. They are separated by double concave spaces, which served for the passage of the tube feet (or of the ampullæ, if, as is not improbable, the tube feet were arranged on the Asteroid type). The adambulacral plates are long and quadrangular, running parallel to the arms, each slightly longer than the corresponding ambulacral ossicle.

The actinal aspect of the arms is not well exposed in any of the specimens; in one, however, the end faces of the adambulacral plates are seen, as at their aboral extremities they curve actinally.

Neither the articular facets of the ambulacral ossicles nor the arm spines are shown.

Locality and stratigraphical position.—The specimens were found in the so-called "Mayhill Sandstone" of Moonee Ponds, Flemington, near Melbourne; they are Upper Silurian in age, but there seems no sufficient reason for regarding the beds from which they have been derived as in any way the equivalent of our Mayhill Sandstone.

The rock is a yellowish, fine-grained, micaceous sandstone, from which all calcareous matter has been dissolved, so that the fossils occur only as casts and impressions coloured by iron oxide.

Affinities of the species.—The only species of *Protaster* for which this could be mistaken is *P. leptosoma*, Salter, from the Leintwardine Flags of Ludlow; from this, however, it may be readily distinguished by the shape of the mouth-frames and of the ambulacral ossicles.

In a list of fossils from the Upper Silurian rocks of Victoria, published by F. M'Coy in 1874,[1] the MS. name of *Tæniaster australis* is recorded from the Upper Yarra. This may refer to the species here described, which at first sight, in specimens that do not show the disk, is not unlike a *Tæniaster*; in the absence of any description of M'Coy's species, it is quite impossible to say whether such is the case, and as the specimens do not come from the same locality, though some of the Asteroids recorded are from Moonee Ponds, it would not be safe to adopt M'Coy's manuscript name. It serves, however, to remind us of the differences of opinion as to the relations of *Tæniaster* and *Protaster*, which Hall[2] maintained were very closely allied, if not identical, attributing the supposed differences between them to errors in description by Salter.[3] According to the original description by Billings,[4] *Tæniaster* differed from *Protaster* in the absence of a disk, in the development of the oral plates from the adambulacral plates and not from the ambulacral elements, and in that the pores pass through the spaces between the

[1] R. B. Smyth, Progress Reports, Geol. Survey, Victoria, No. 1, Melbourne, 1874, p. 34.

[2] J. Hall, 20th Regents Report, Albany, 1867, pp. 293–4 and 300–1.

[3] J. W. Salter, On some new Palæozoic Starfishes, Ann. and Mag. Nat. Hist. ser. 2, vol. xx. 1857, pp. 330–2, pl. ix. figs. 4 and 5; and Additional Notes on some new Palæozoic Starfishes, ser. 3, vol. viii. 1861, pp. 484–6, pl. xviii. figs. 9, 10, and 11.

[4] E. Billings, On the Asteriadæ of the Lower Silurian Rocks of Canada, Canadian Org. Remains, dec. iii. Montreal, 1858, p. 80–1, pl. x. figs. 3 and 4.

ambulacral ossicles and the two adjoining adambulacral plates, and not through the body of the ambulacral ossicle itself. Hall has claimed to have discovered traces of a disc in Billings's type specimens of *Tæniaster*, and if so, this distinction falls to the ground; but, in regard to the two other points, the collection of specimens of *P. Miltoni* in the British Museum Collection confirm the correctness of Salter's views. The differences are, therefore, valid ones, and both genera must be retained, as has been done by Zittel. This new species differs from *Tæniaster* in the presence of the disk, though, as we have seen, this distinction may possibly not hold good, and in the structure of both arms and oral pentagon. It undoubtedly differs from the other species of *Protaster* in many important points of structure, and herein agrees more closely with *Brisinga* than does any Protophiuroid yet described; to mark this resemblance the specific name has been given. But the other species of *Protaster* differ among themselves in equally important points, and the genus is apparently constituted by a group of species which careful revision and further knowledge of their structure would probably relegate to more than two distinct genera. The necessity for such a revision has been recently urged by Sturtz,[1] and to this with a discussion of some questions in their anatomy and the significance of some points in the structure of *P. brisingoides*, I hope subsequently to return. Till such has been done, it seems advisable to include this species in the comprehensive genus *Protaster*.

VI.—Note on the Genera *Tristychius* and *Ptychacanthus*, Agassiz.

By Dr. R. H. Traquair, F.R.S., F.G.S.

Some years ago,[2] in showing that the spines supposed by Hancock and Atthey to be dorsal spines of *Gyracanthus* were merely young and unworn specimens of lateral spines of the same genus, I called attention to the general fact that young examples of Selachian spines could not be expected to represent the older ones in miniature, and *vice versa*.

For as the spine increases in size by growth at the base, the young one is consequently represented only by the distal portion of the adult. And as in the process of growth, differences in sculpture and proportions may supervene, the general characters may be so altered, that if the distal portion be lost by attrition, the old and young individuals may be with difficulty recognizable even as belonging to the same genus.

Such an instance may, I think, be found in the spines named by Agassiz respectively *Tristychius arcuatus* and *Ptychacanthus sublævis*, both from the Lower Carboniferous rocks of Central Scotland.

In very young specimens of the former the surface of the exserted portion is entirely covered with longitudinal ridges and sulci, and

[1] B. Sturtz, Beitrag zur Kenntniss palæozoischer Seesterne, Palaeontographica, vol. xxxii. Stuttgart, 1886, p. 79.

[2] Ann. and Mag. Nat. Hist. ser. 5, vol. xiii. 1884, p. 37.

there is scarcely any posterior area, the two rows of marginal denticles being placed close to each other and alternating. As the spine increases in length, the ridges begin to drop off behind, so that in examples of from three to four inches in length, like Agassiz's type,[1] only the tip is ridged all round, while three ridges, one median and two lateral, persist beyond the other along the front, whence the name *Tristychius*. Along with this change in sculpture, the two posterior rows of denticles diverge from each other, and a well-marked *area* is formed between them as in *Ctenacanthus*.

In still larger spines the sulcated tips become entirely worn off, leaving only the three anterior ridges, which in turn also finally disappear in examples which have been subjected to any considerable amount of wearing. A somewhat short, gently-curved, bluntly-pointed spine now confronts us, destitute of ridges or sulci, and with the surface covered only by very close and delicate striæ. Such spines are indistinguishable from Agassiz's description and figure of *Ptychacanthus sublævis*,[2] of which the original seems unfortunately to be lost, for although Agassiz states that it belonged to Professor Jameson, I have never been able to find it in the Edinburgh Museum.

Ptychacanthus sublævis then represents to my mind nothing but an adult *Tristychius arcuatus*, with the point broken off, and the general surface a little worn, and this view is, I consider, not only corroborated, but proved by a series of specimens of undoubted *Tristychius* in the Edinburgh Museum.

NOTICES OF MEMOIRS.

I.—*Amblypristis Cheops*, nov. gen. et. sp., aus dem Eocaen Aegyptens. By Prof. Dr. W. Dames. Sitzungsb. Ges. naturf. Fr. Berlin, 1888, No. 6.

THIS paper forms an interesting contribution to our knowledge of the fossil vertebrate fauna of Birket-el-Qurūn, in Fajum, for which we are already indebted to Dr. Dames (Sitzungsb. königl. Akad. Wiss. Berlin, 1883, pt. i.). The evidence of the new Saw-fish (*Amblypristis Cheops*) consists in some detached rostral teeth, differing from those of the existing *Pristis* in their shortness and great relative breadth. One example is figured; and Dr. Hilgendorf adds a brief note on the structure of the rostral teeth of the living genus, as compared with the fossil.

II.—On some Devonian Crustacea. By Rev. G. F. Whidborne, M.A., F.G.S.[3]

BESIDE species of Crustaceans already described from Woulborough and Lummaton, several new species are found there, as the following: *Phacops batracheus*, which differs from *P. fecundus*, Barr., in the rearward position of the eye and more overhanging glabella; *Proetus batillus*, which has a flatter glabella than *P.*

[1] Poiss. Foss. tome iii. tab. 1*a*, fig. 9–11.
[2] Op. cit. tome iii. tab. 5, fig. 1-3.
[3] Revised abstract of paper read at the British Association.

bohemicus, Barr., more anterior eyes, and longer cheek spines; *P. subfrontalis*, which approaches *P. frontalis*, Barr., but has a much squarer glabella; *P. audax*, which is like *P. granulosus*, Goldf., but has tuberculated cheeks; *Cyphaspis ocellata*, like *C. ceratophthalmus*, Sandb., but with long sharp cheek spines; *Lichas devonianus*, having a wider head than *L. Haueri*, Barr., larger eyes surrounded by tubercles, and a more arched neck; *Acidaspis Robertsii*, with narrower cheeks than *A. lacerata*, Barr.; *A. Hughesii*, with a bilobed tail surrounded by a flat border bearing aciculate spines; *Bronteus delicatus*, having its glabella marked with transverse lines, and smaller spots than in *B. flabellifer*, Goldf.; *B. pardalios*, which is more coarsely tuberculated than *B. granulatus*, Goldf.; *Entomis peregrina*, distinguishable from *E. tuberosa*, Jones, by the indistinctness of its nodule; and *Bactropus decoratus*, dissimilar from *B. longipes*, Barr., in being much smaller and more coarsely striated.

The *Cheirurus* of these beds is not *Ch. articulatus*, Münst., but a new species, *C. Pengellii*, differing from it in the shorter front lobe of its glabella. The true *B. flabellifer*, Goldf., occurs, not at Woulborough, but at Chircombe Bridge, where it is accompanied by *Dechenella setosa*, n.sp., differing from *D. Verneuili*, Barr., in having nineteen segments on the tail.

III.—On some Devonian Cephalopods and Gasteropods. By Rev. G. F. Whidborne, M.A., F.G.S.

THE following new species occur at Woulborough or Lummaton, or in the case of some of the Gasteropods at Chudleigh: *Goniatites obliquus*, a large shell with open umbilicus, flat sloping sides and narrow flat back; *G. psittacinus*, a small tumid shell with closed umbilicus, rounded whorls, slightly curved sutures; *G. nuciformis*, with minute umbilicus and much broader back than the preceding; *G. aratus*, a flatter shell with small umbilicus, and marked with four angulated sulci; *G. pentangularis*, with open spire, inner whorls ribbed, and section of whorls pentagonal; *G. Hughesii*, large and flat with closed umbilicus, evenly rounded back and minutely striated surface; *Cyrtoceras Leei*, a large curved conoidal form with more irregular and dilate lamellæ than *C. fimbriatum*, Ph.; *C. pulcherrimum*, unlike *C. reticulatum*, Ph., in having tubercles on the shoulder instead of ribs; *C. Vicarii*, having a broader section, and much fewer tubercles than the last; *C. præclarum*, more involute and elliptical than the last, with wider mouth and oblique ridges crossed by distant striæ; *C. majesticum*, large and smooth, with oval mouth, narrow chambers and imperfect spire; *Hercoceras inornatum*, differing from *H. subtuberculatum*, Sandb., in being smooth; *Orthoceras hastatum*, more conical and with fewer annulæ than *O. tubicinella*, Ph.; *O. Vicarii*, differing from *O. pulchellum*, F. A. Röm., in being round and not oval in section; *O. comatum*, which is *O. tubicinella*, Sandb., not Ph.; *Phragmoceras vasiforme*, which is rather less convex than *Ph. subpyriforme*, Mü.; *Ph. ungulatum*, small and more arched than *C. cornucopia*, Sandb.; *Ph. Marri*, conical and transversely flattened, approaching *G. Conradi*, Barr.; *B. mundus*,

with broad grooved keel, and very transverse kidney-shaped mouth; *Euomphalus fenestralis*, with a depressed spire and three ridges cancellated by numerous rings; *Pleurotomaria perversa*, a large sinistral shell, unlike *Pl. expansa*, Ph., in having spiral striæ, a deeper suture, whorls more convex; *Pl. victrix*, which has an elevated spire, angulated whorls, central sinus band, and a few spiral striæ; *Pl. Chudleighensis*, separated from the preceding in having its spiral ridges crenulated, and the sinus band much higher; *Littorina devonaic*, having the general shape of *Purpura lapillus*, with eight spiral rows of tubercles which are largest near the suture; *Monodonta archon*, very large and trochiform, with flat base and sides, linear suture and oblique growth-lines; *Phorus philosophus*, with a low spire, wide umbilicus and convex whorls bearing fragments of broken shells; *Macrocheilus tumescens*, a much more globular form than *M. subcostatus*, Schlot.; *Turbo Pengellii*, unlike *T. subangulosus*, d'A. and de V., in its wider flatness above the shoulder; *Loxonema scalaroides*, very elongate, with its convex whorls crossed by discontinuous varices; *H. duplisulcata*, differing from *H. tenuisulcata* in possessing a series of subsidiary striæ; *Acroculia columbina*, a wide depressed form with fine waving longitudinal markings; *Metoptoma cordata*, like *M. pileus*, Ph., but with loftier umbo and more angulated mouth; and *Chiton papilio*, which comes midway between *Ch. corrugatus*, Sandb., and *Ch. sagittalis*, Sandb.

The above are accompanied by *Orthoceras Oceani*, d'Orb. (= *O. cinctum*, Ph.), *O. tenuistriatus*, Mü., *O. subfusiforme*, d'A. and de V., *O. regularis*, Mü., *O. subarmularis*, Mü., *B. lineatus*, Goldf. (= *B. striatus*, Ph.), *P. bifida*, Sandb. (=*B. Woodwardii*, Ph.), *Eu. serpula*, de Kon., *Eu. planorbis*, d'A. and de V., *Eu. lævis*, d'A. and de V., *Eu. rota*, Sandb., *Eu. decussatus*, Sandb., *Eu. germanus*, Ph. sp., *Eu. catenulatus* (=*Eu. serpens*, Ph., Pal. Foss. fig. 172, *f.* and *g.* only), *Pl. D'Orbigniana*, d'A. and de V., *Pl. subclathrata*, Sandb., *Pl. Lousdalii*, d'A. and de V., *Pl. delphinuloides*, Schlot., *Pl. calculiformis*, Sandb., *Pl. trochoides* (=*Pl. monilifera*, Ph. Pal. Foss.), *Pl. distinguenda* (=*Pl. aspera*, Ph. Pal. Foss.), *N. deformis*, Sow., *N. piligera*, Sandb., *T. multispira*, Sandb.? *L. purpura*, d'A. and de V., *L. subcostata*, d'A. and de V., *Scalaria antiqua*, Mü., *M. subcostatus*, Schlot. (=*M. arculatus*, Ph., and *M. elongatus*, Ph.), *Scoliostoma texatum*, Ph. sp., *Sc. gracile*, Sandb., *Holopella tenuicostata*, Sandb., *H. tenuisulcata*, Sandb., *H. piligera*, Sandb., *Acroculia multiplicata*, Giebel, and *A. proæva*, Eichw.

IV.—Note on Graptolites from Dease River, B.C.[1] By Prof. Charles Lapworth, LL.D., F.R.S., F.G.S.

In June, 1887, a small collection of Graptolites was obtained by Dr. G. M. Dawson on Dease River, in the extreme northern and inland portion of British Columbia, about lat. 59° 45′, long. 129°. These fossils were derived from certain dark-coloured, carbonaceous and often calcareous shales, which in association with quartzites and

[1] Reprinted from the "Canadian Record of Science."

other rocks, characterize a considerable area on the lower part of the Dease, as well as on the Lizard River, above the confluence. The collection referred to was transmitted by Mr. J. F. Whiteaves to Prof. Lapworth, whose special studies on Graptolites are well known. It is believed that the following preliminary note by Prof. Lapworth will be of interest, as the occurrence of Graptolites on the Dease River extends very far to the north-westward of our previous knowledge of the occurrence of these forms in North America. In 1886 a similar small collection was obtained by Mr. R. G. McConnell near the line of the Canadian Pacific Railway, in the Kicking Horse (Wapta) Pass. This and the new locality here described are the only ones which have yet been found to yield Graptolites in the entire western portion of the Dominion.

Prof. Lapworth, under date December 13th, writes as follows:—

I have, to-day, gone over the specimens of Graptolites, collected by Dr. Dawson, from the rocks of the Dease River, British Columbia. I find that they are identical with those examined by me from the rocks of the Kicking Horse Pass, some time last year. The species I notice in the Dease River collection are:

Diplograptus euglyphus, Lapworth.
Climacograptus comp. *antiquus*, Lapw.
Cryptograptus tricornis, Carruthers.
Glossograptus ciliatus, Emmons.
Didymograptus comp. *sagittarius*, Hall.
New form allied to *Cœnograptus*.

These Graptolite-bearing rocks are clearly of about Middle Ordovician age. They contain forms I would refer to the second or Black River Trenton period: i.e. they are newer than the Point Lévis series, and older than the Hudson and Utica groups. The association of forms is such as we find in Britain and Western Europe, in the passage-beds between the Llandeilo and Caradoc Limestones. The rocks in Canada and New York, with which these Dease River beds may be best compared, are the Marsouin beds of the St. Lawrence Valley, and the Norman's Kill beds of New York. The Dease River beds may perhaps be a little older than these.

Mr. C. White described some Graptolites from beds in the mountain region of the West, several years ago, which may belong to the same horizon as the Dease River zones, though they have a somewhat more recent aspect.

The specific identification of the Dease River fossils, I regard as provisional. While the species correspond broadly with those found in their eastern equivalents, they have certain peculiarities which may, after further study, or on the discovery of better and more perfect specimens, lead to their separation as distinct species or varieties.

It is exceedingly interesting to find Graptolites in a region so far removed from the Atlantic basin, and also to note that the typical association of Llandeilo-Bala genera and species is still retained practically unmodified.—G. M. D.

REVIEWS.

I.—The History of Volcanic Action during the Tertiary Period in the British Isles. By Archibald Geikie, LL.D., F.R.S., Director-General of the Geological Survey of the United Kingdom. (Transactions of the Royal Society of Edinburgh, vol. xxxv. 1888, pp. 21-184, with 2 Maps and 53 Woodcuts. Reprinted, 4to. Edinburgh, R. Grant & Son. Price 18*s*.)

THE work before us, probably the most important of the original papers by the author, must be read by every one devoted to the special study of volcanic action; at the same time it contains results of such high interest to all geologists, that in due course it will doubtless be regarded as one of the 'classic' memoirs of this prolific age.

At the outset the author gives a brief sketch of the labours of previous observers. Foremost among these was Macculloch, and of his great work on the Western Islands of Scotland, Dr. Geikie says, "Few single works of descriptive geology have ever done so much to advance the progress of the science in this country." It is pleasant to see the labours of the pioneers so fully acknowledged, and in reference to Ami Boué, who published in 1820 his *Essai géologique sur l'Ecosse*, it is remarked that "the value of this work as an original contribution to the geology of the British Isles has probably never been adequately acknowledged."

From time to time during the past 30 years Dr. Geikie has published the results of his own observations on the volcanic rocks of Scotland, but it was not until 1879 that he "appreciated for the first time the significance of Richthofen's views regarding 'massive' or 'fissure-eruptions,' as contradistinguished from those of central volcanoes like Etna or Vesuvius;" then, however, when traversing some portions of the volcanic region of Wyoming, Montana, and Utah, he "saw how completely the structure and history of these tracts of Western America explain those of the basalt-plateaux of Britain."

In the mean time an elaborate Memoir by Prof. Judd on the Ancient Volcanoes of the Highlands was read before the Geological Society of London; and it is important to notice that the conclusions of Dr. Geikie are to a very large extent at variance with those of Prof. Judd. The latter had recognized the basal wrecks of five great central volcanoes in the Western Islands; whereas Dr. Geikie has not been able to discover evidence of any great central volcanoes, and has found the order of outflow of the successive groups of rocks to have been the reverse of what Prof. Judd believed it to be.

In the present memoir Dr. Geikie commences his history of volcanic action with an account of the basic dykes, which traverse so large a part of Scotland, and extend also into the North of Ireland, the Isle of Man, and the North of England. Of these dykes, that in Cleveland is one of the best-known English examples. The author then describes the great volcanic plateaux, which, in spite of vast denudation, still survive in extensive fragments in Antrim and

the Inner Hebrides. The eruptive bosses of basic rocks that have broken through the plateaux are next discussed, and then an account is given of the protrusions of acid rocks that mark the latest phase of eruption in the region.

Finally, the leading features in the history of Tertiary volcanic action in the British Isles are summarized by Dr. Geikie, whose words we quote as far as possible in our condensed account of his views.

The earliest beginnings of the volcanic disturbances may possibly go back into the Eocene period, and the final manifestations may not have ceased until Miocene times, or perhaps later.

These disturbances originated from a vast subterranean lake or sea of molten rock, which appeared beneath the volcanic region as it underwent elevation. Enormous horizontal tension arose, and a system of approximately parallel fissures opened in the terrestrial crust, having a general direction towards N.W. The majority of the fractures did not reach to the surface of the ground, though probably not a few did so. No sooner were the fissures formed than the molten lava underneath was forced upward into them for many hundred or even thousands of feet above the surface of the subterranean lava-sea. Solidifying between the fissure-walls, the lava formed the numerous basic dykes that constitute the widespread and distinctive feature of the volcanic region.

Where the fissures reached the surface or near to it, the molten rock sought relief by egress in streams of lava, of which abundant remains are still left in the basalt-plateaux of Antrim and the Inner Hebrides.

In some places, the accumulated pile of such ejections, which include layers of fine tuff, etc., even now exceeds 3000 feet. The surface over which the lava flowed seemed to have been mainly terrestrial, for here and there, between the successive sheets of basalt, the remains of land-plants and also of insects have been discovered.

Subsequently there uprose at certain points, coarsely crystalline basic rocks, which solidified as dolerites, gabbros, etc.

Probably long after the eruption of the gabbros, a renewed outbreak of subterranean activity gave rise to the protrusion of rocks of a markedly acid type. They include varieties that range from felsites through porphyries and granophyres into granite.

Around the bosses of gabbro and granophyre, the bedded basalts have undergone considerable contact-metamorphism; and it is interesting to learn that the former precisely resemble rocks of similar kinds in Palæozoic and Archæan formations.

Ultimately another system of basic dykes was formed; dykes which cross those of earlier date, and rise through the other volcanic rocks.

We have passed over the more detailed portions of this work, contenting ourselves with pointing out the leading conclusions of the author. These are indeed based on extensive microscopic investigations of the rocks, as well as on the more important field-work. Further particulars, however, of the microscopic petrography are promised in a future memoir on the subject, by Dr. F. H. Hatch, whose assistance is cordially acknowledged by the author.

II.—A Bibliography of the Foraminifera, Recent and Fossil, from 1565 to 1888. By C. D. Sherborn, F.G.S. 8vo. pp. vi. and 152. (London, Dulau & Co., 1888.)

IN the July Number, 1887, of the Geol. Mag., at p. 324, we briefly criticized a "Bibliography of the Foraminifera," by Prof. Anthony Woodward; and we regretted to point out some of its errors and shortcomings. We can now congratulate Rhizopodists on the publication of a good catalogue of all the books and memoirs treating of Foraminifera that have appeared during more than the last three centuries. The little shelled Protozoans under notice, always either quaint or elegant in form, and offering an interminable series of varied shapes to the microscopist, and highly interesting subjects of research to the biologist, have been treated of in hundreds of works with more or less exactness, and illustrated by thousands of plates of very different values. The bibliographies hitherto given to the public, within the last forty years, have been more or less useful as clues in the finding of some desiderata; but have often disappointed the student, or left him vaguely conscious that more or better work had been done in his line of research. If really desirous of learning what others have worked out, and of comparing the results of those who have preceded him, he now has good aid in his search, and has no excuse should he ignore earlier workers.

Having entered on the study of Foraminifera, and finding it necessary to master their bibliographic history, in making tables and catalogues of the multitudinous genera and species already recorded, Mr. C. D. Sherborn evidently found existing bibliographies too imperfect for the purpose, and therefore consolidated and augmented the several lists, which books and friends supplied, as fully explained in his Preface. The result is this excellent Bibliography before us, which has been earnestly and conscientiously carried out, with scrupulous exactness as to dates and titles of books and memoirs, the places of publication, the life-dates of the authors (when obtainable), and a definite uniformity in quoting periodicals and transactions, which especially is as valuable as it is rare. The frequent notes relative to some rare and other publications are of great value: and the enumeration of, or remarks on, the illustrations seem to intimate that the author of this "Bibliography" could supply an index of genera and species, very many of which are notoriously synonymous, having been determined and published without due regard to previous publications.

Mr. Sherborn has adopted the plan of enumerating the authors (about 700) in alphabetical order, and the works of each in order of date (about 2000), with cross-references. Of the books and papers thus mentioned only about 20 are noted as not having been seen, with such care and exactness has the work been carried out. There is a very short list of *errata* in the book, and scarcely any others can be found even after a considerable use of this valuable Bibliography. Strata of various ages have yielded so many Foraminifera that the geological formations are frequently mentioned in connection with them in the titles and pages of the books and memoirs here enumerated;

hence the Geologist, as well as the Biologist, has an interest in this Bibliography, which we cordially recommend to both as highly necessary in their researches.

III.—Tabular Index to the Upper Cretaceous Fossils of England and Ireland, cited by Dr. Charles Barrois in his "Description Géologique de la Craie de l'Ile de Wight," Paris, 1875, and "Recherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irlande," Lille, 1876. By E. Westlake, F.G.S. 4to. pp. 24 (Fordingbridge, Mitchell, 1888.)

THIS tabular list gives the geological distribution in the different zones of the Cenomanian, Turonian and Senonian divisions, of 405 species of Cretaceous fossils, referred to in the above-named works of Dr. Barrois; and also references to the localities where they occur. It appears to have been very carefully compiled, and should prove of very material assistance to all workers in the Cretaceous rocks of this and other countries.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—November 7, 1888.—W. T. Blanford, LL.D., F.R.S., President, in the Chair.—The following communications were read:—

1. "The Permian Rocks of the Leicestershire Coal-field." By Horace T. Brown, Esq., F.G.S.

The author considers that whilst rocks belonging to the Carboniferous and Trias have been mapped as Permian, true representatives of the Permian do exist in the district to a considerable extent. The Bunter conglomerates rest for the most part upon the truncated edges of Carboniferous strata; but intercalated between them and the Carboniferous, at various points, are thin beds of purple marly breccias and sandstones seldom exceeding from 30 to 40 ft., but differing in lithological character from the overlying and underlying rocks. The brecciated series rests with striking unconformity upon the Carboniferous. Moreover, the Boothorpe fault, which throws the Coal-measures 1000 ft., affects the overlying brecciated series to an extent of not more than from 20 to 30 ft. The unconformity between the brecciated series and the Bunter is less obvious. Sections establishing the double unconformity were described in considerable detail. Attention was also called to other localities within the Coal-field where Permian rocks exist, the author having in many cases mapped their boundaries.

He further called attention to certain beds which have been erroneously classed as Permian by the Survey. The first of these is a patch at Knowle Hills. Making extensive use of the hand-borer, he found that the greater part of the so-called Permian consists of a wedge-shaped piece of Lower Keuper let down by a trough fault. The so-called Moira grits belong to and are conformable with the ordinary Coal-measures of the district.

The lithological characters of the Leicestershire Permians is sufficient to differentiate them from the Trias and Carboniferous. They consist of red and variegated marls, bands of breccia, and beds of fine-grained yellowish sandstone; the breccia fragments are of great variety and little waterworn. These are imbedded in a bluish-grey matrix, hard or soft, which consists of insoluble matter united by the carbonates of lime and magnesia with some hydrated ferrous oxide, which on exposure becomes oxidized.

The breccias have a tendency to die out northwards. The most abundant materials are quartzo-felspathic grits with associated grey flinty slates (Older Palæozoic), with in addition vein-quartz, volcanic ash, and igneous rocks. The Carboniferous rocks afford argillaceous limestone, Mountain Limestone, grits, and hæmatite. At Boothorpe nearly 90 per cent. is made up of the old Palæozoic material, whilst at Newhall Park 28·8 per cent. consists of Carboniferous grits and hæmatite. The quartzite fragments resemble those of the lower part of the Hartshill series, but the existence of "strain shadows" indicates a difference subsequently explained. A very few fragments may be referred to the Charnwood rocks.

The bulk of the material has a southern origin, and the irregularity of the fragments proves that they cannot have come from a distance. Evidence is given of the probable existence of a ridge of older Palæozoics, from which the Carboniferous rocks had been stripped, beneath the Trias of Bosworth. (There is an actual outcrop of Stockingford shales at Elmesthorpe.) The direction of this line is parallel with the Nuneaton-Hartshill and Charnwood axes of elevation, and also with the general direction of the major folds and faults of the Leicestershire Coal-field. The northern part of this ridge, which is apparently a faulted anticlinal, is a very probable source of the angular fragments occurring in the Permian breccias 5 or 6 miles to the north-west.

The author concluded that the Permian rocks of the Leicestershire Coal-field belong to the same area of deposition as those of Warwickshire and South Staffordshire, all having formed part of the detrital deposits of the Permian Lake which extended northwards from Warwickshire and Worcestershire, and which had the Pennine chain on its eastern margin. He pointed out the dissimilar nature of these deposits to those of the eastern side of the Pennine chain from Nottingham to the coast of Durham. There were proofs of the existence of a land barrier, owing to the uprising of the Carboniferous, between the district round Nottingham and the Leicestershire Coal-field. The most northerly exposure of the Leicestershire Permians is 13 miles S.W. of those of South Notts. He indicated the probable course of the old coast-line of the western Permian Lake. Denudation had bared some of the older Palæozoics of their overlying Coal-measures, and it is the rearranged talus from the harder portions of these older rocks which now form the brecciated bands in the Leicestershire Permian.

In an Appendix some igneous rocks found in the Bosworth borings were described.

2. "On the Superficial Geology of the Central Plateau of North-western Canada." By J. B. Tyrrell, Esq., B.A., F.G.S., Field Geologist of the Geological and Natural History Survey of Canada.

The Drift-covered prairie extends from the west side of the Lake of the Woods to the region at the foot of the Rocky Mountains, rising from a height of 800 feet on the east to 4500 feet on the west, the gentle slope being broken by two sharp inclines known as the Pembina Escarpment and the Missouri Coteau, giving rise to the First, Second, and Third Prairie Steppes.

The author described the older rocks of this region, referring especially to his subdivision of the Laramie Formation into an Edmonton Series of Cretaceous age, and a Pascapoo Series forming the base of the Eocene, and then discussed the Superficial Deposits in the following order:—

1. *Preglacial gravels* occurring along the foot of the Rocky Mountains, composed of waterworn quartzite pebbles, similar to those now forming and, like them, produced by streams flowing from the mountains.

2. *Boulder-clay* or *Till*, having an average thickness of 50–100 feet, and filling up pre-existing inequalities. The clay is essentially derived from the material of the underlying rocks. The smoothed and striated boulders of the western region are largely quartzites derived from the Rocky Mountains; these gradually disappear towards the east, and are replaced by gneisses and other rocks transported from the east and north-west. Towards the north-west several driftless hills over 4000 feet high appear to have stood as islands above the sheet of ice. Some of the surface erratics of gneissose rock have doubtless been derived from the Till, whilst others are connected with moraine deposits, and others, again, appear to have been dropped from bergs floating in seas along the ice-front. The Till is sometimes divisible into a lower massive and upper rather stratified deposit, separated occasionally by

3. *Interglacial Deposits* of stratified material, with seams of impure lignite, and shells of *Pisidium*, *Limnæa*, *Planorbis*, etc.

4. *Moraines*, which are intimately associated with the Boulder-clay, and represent terminal moraines of ancient glaciers which originated upon or crossed the Archæan belt. One of these is the well-known Missouri Coteau.

After pointing out the derivation of quartzite pebbles in the drifts of the eastern region from Miocene conglomerates, and not directly from the Rocky Mountains, the author described

5. The *Kames* or *Åsars* generally occurring at the bottoms of wide valleys, and which resemble in structure those of Scandinavia.

6. *Stratified Deposits* and Beach-ridges which have been formed at the bottoms and along the margins of freshwater-lakes lying along the foot of the ice-sheet. The principal of these occupied the valley of the Red River, and has been called Lake Agassiz; it had a length of 600 miles and a width of 170 miles. The author described in detail the gravel terraces formed around this lake, and showed that a slow elevation had taken place towards the north and east

since their formation. He favoured the view that the waters of the lake were dammed by the ice towards the north. An account was given of some quartzite flakes, apparently chipped by human agency, in one of the terraces of this lake. On the recession of the ice the southern drainage-channel was abandoned, and a northerly one opened out.

7. *Old Drainage-channels.*—Throughout the whole region old drainage-channels appear to have been occupied by southerly running rivers (where the present drainage is northerly), and are considered to have carried away the waters draining from the foot of the ice. Some of these valleys have been blocked by moraines in the Duck Mountains, the result of local glaciers.

II.—November, 21, 1888.—W. T. Blanford, LL.D., F.R.S., President, in the Chair.

W. Whitaker, Esq., B.A., F.R.S., F.G.S., who exhibited a series of specimens from the deep boring at Streatham, made some remarks upon the results obtained, of which the following is an abstract :—

After passing through 10 feet of gravel, etc., 153 of London Clay, 88½ of Lower London Tertiaries, 623 of Chalk (the least thickness in any of the deep borings in and near London), 28½ of Upper Greensand, and 188½ of Gault, at the depth of 1081½ feet hard limestone, mostly with rather large oolitic grains, was met with. This, with alternations of a finer character, sandy and clayey, lasted for only 38½ feet, being much less than the thickness of the Jurassic beds, either at Richmond or at Meux's Boring. The general character of the cores showed a likeness to the Forest Marble, and the occurrence of *Ostrea acuminata* agreed therewith.

At the depth of 1120 feet the tools entered a set of beds of much the same character as those that had been found beneath Jurassic beds at Richmond, and beneath Gault at Kentish Town and at Crossness. The softer and more clayey components were not brought up; the harder consist of fine-grained compact sandstones, greenish-grey, sometimes with purplish mottlings or bandings, and here and there wholly of a dull reddish tint. With these there occur hard, clayey, and somewhat sandy beds, which are not calcareous, whilst most of the sandstones are. Thin veins of calcite are sometimes to be seen, and at others small concretionary calcareous nodules ; but no trace of a fossil has been found.

The bedding is shown, both by the bands of colour, and by the tendency of the stone to fracture, to vary generally from about 20° to 30°.

In the absence of evidence it is hard to say what these beds are, and the possibilities of their age seem to range from Trias to Devonian. It is to be hoped that this question may be solved, as on it depends that of the possibility of the presence of Coal-measures in the district; and Messrs. Docwra, the contractors of the works, have with great liberality undertaken to continue the boring operations at their own expense for at least another week.

Details of the section will be given in a forthcoming Geological

Survey Memoir, in which, moreover, the subject of the old rocks under London will be treated somewhat fully.

The following communications were read :—

1. "Notes on the Remains and Affinities of five Genera of Mesozoic Reptiles." By R. Lydekker, Esq., B.A., F.G.S.

This paper was divided into five sections. In the first the author described the dorsal vertebra of a small Dinosaur from the Cambridge Greensand, which he regarded as probably identical with the genus *Syngonosaurus*, Seeley. Reasons were then given for regarding this form as being a member of the Scelidosauridæ, stress being laid on the absence of a costal facet on the centrum.

The second section described an axis vertebra from the Wealden of the Isle of Wight, which is evidently Dinosaurian, and may possibly belong to *Megalosaurus*. It is remarkable for exhibiting an intercentrum on its anterior aspect, and also for the absence of anchylosis between its centrum and that of the atlas.

In the third section the femur of a small Iguanodont from the Oxford Clay, in the possession of A. R. Leeds, Esq., was described. This specimen agrees with *Hypsilophodon* and *Camptosaurus* in its pendent inner trochanter, and it was referred to the latter genus as *C. Leedsi*. It is also considered to be closely allied to *Iguanodon Prestwichi*—the type of *Cumnoria* of Seeley—which is also considered to belong to the American genus. The name *Camptosaurus valdensis* was applied to an allied form from the Wealden; and the name *Cryptodraco* proposed to replace *Cryptosaurus*.

The imperfect skeleton of a Sauropterygian from the Oxford Clay near Bedford, which formed the subject of a previous communication, was redescribed. This specimen was identified with *Plesiosaurus philarchus*, Seeley, which it was proposed to refer to a new genus under the name of *Peloneustus*. This genus was shown to be allied to *Pliosaurus*, and to be represented by forms in the Kimmeridge Clay which have been described as *Plesiosaurus æqualis* and *P. stenodirus*. It was also compared with the genus *Thaumatosaurus*, Meyer, from which *Rhomaleosaurus* of Seeley was considered inseparable. Some remarks are added on other Sauropterygians; and it was proposed to adopt the name *Cimoliosaurus* for all the forms having a pectoral girdle of the type described under the names of *Elasmosaurus* and *Colymbosaurus*, and with single costal facets to the cervical vertebræ.

The paper concluded with a notice of the affinities of the Crocodilian genus *Geosaurus*. This form was shown to be closely allied to *Metriorhynchus*, both being characterized by the absence of dermal scutes and the presence of bony plates in the sclerotic. It was also shown that some of the species of *Cricosaurus* belong to the former genus; while there appear to be no grounds by which *Dacosaurus* (*Plesiosuchus*) can be separated from the same.

2. "Notes on the Radiolaria of the London Clay." By W. H. Shrubsole, Esq., F.G.S.

Microscopical examination of the London Clay of Sheppey and elsewhere has afforded proof of the existence of a Diatomaceous zone

near the base of the formation. The formation of a well for the Queenborough Cement Company in 1885 was the means of furnishing a laminated clay with glittering patches of Diatoms from a depth of 225 feet. In this were also found fairly good pyritized specimens of Radiolaria, some of which were submitted to Prof. Ernst Häckel, who found a large number of fragments of Tertiary Radiolaria, but few well-preserved specimens appertaining to the families Sphæroidea, Discoidea, and Cyrtoidea, and apparently identical with those described from the Tertiary Tripoli beds of Grotte. No new species occurred among the recognized forms.

Sketches made by Mr. A. L. Hammond were also submitted to Prof. Häckel, who stated that these forms were not identical with any known species, recent or fossil.

The author described the following new species:—*Cornutella Hammondi, Spongodiscus asper,* and *Monosphæra toliapica.*

The specimens were preserved in iron-pyrites.

Some Tetractinellid sponge-spicules from the washings were recognized by Prof. Sollas.

3. "Description of a New Species of *Clupea* (*C. vectensis*) from Oligocene Strata in the Isle of Wight." By E. T. Newton, Esq., F.G.S.

A number of small fishes found by Mr. G. W. Colenutt, of Ryde, during his investigations of the Oligocene strata of the Isle of Wight, in beds belonging to the "Osborne Series," were described as belonging to a new species of *Clupea.* The specimens vary in length from 20 to nearly 60 millim. In all of them the head is much broken; but the rest of the body is beautifully preserved, showing most distinctly the vertebral column, ribs, fins, tail, and ventral spines. The single dorsal fin has its front rays about midway between the tip of the snout and the base of the tail, the ventral fins being immediately under the front of the dorsal and about midway between the pectoral and anal fins. The anal fin commences about halfway between the ventral fins and the base of the tail, occupying about two-thirds of that distance, and the tail is deeply forked. The scales are thin and in most cases much broken; while the ventral region of the body is armed with a row of strong spines. The spinal column contains about 40 vertebræ, of which 14 or 15 are caudal. The bones of the head are mostly broken, but those of which the outline can be traced agree with the corresponding parts of the Sprat.

These fishes are referred to the genus *Clupea*; but although very closely allied to the Common Herring and Sprat, the relative positions of the dorsal and ventral fins, as well as the number of vertebræ, prevent their being placed in any known species, either recent or fossil, and they are therefore regarded as a new form and named *Clupea vectensis.*

III.—December 5, 1888.—W. T. Blanford, LL.D., F.R.S., President, in the Chair. The following communications were read:—

1. "Notes on two Traverses of the Crystalline Rocks of the Alps." By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.

These journeys were undertaken in the summer of 1887 in the company of the Rev. E. Hill, F.G.S., in order to ascertain whether the apparent stratigraphical succession among the gneisses and crystalline schists which the author had observed in the more central region of the Alps, held good also in the Western and Eastern Alps. At the same time all circumstances which seemed to throw any light on the origin of the schists were carefully noted. The author examined the rocks along two lines of section:—(1) By the road of the Col du Lautaret from Grenoble to Briançon, and thence by the Mont Genèvre and the Col de Sestrières to Pinerolo, on the margin of the plain of Piedmont. (2) From Lienz, on the upper waters of the Drave, to Kitzbuhel; besides examining other parts of the central range, east of the Brenner Pass. The specimens collected have subsequently been examined microscopically.

The results of the author's investigations may be briefly summarized as follows:—

(1) While rocks of igneous origin occur at all horizons among the crystalline series of the Alps, these, as a rule, can be distinguished; or, at any rate, even if the crystalline schists in some cases are only modified igneous rocks, these are associated with recognizable igneous rocks of later date.

(2) There are, speaking in general terms, three great rock-groups in the Alps which simulate curiously, if they do not indicate stratigraphical sequence. The lowest and oldest resemble the gneisses of the Laurentian series; the next, those rather "friable" gneisses and schists called by Dr. Sterry Hunt the Montalban series; the third and uppermost is a great group of schists, generally rather fine-grained, micaceous, chloritic, epidotic, calcareous and quartzose, passing occasionally into crystalline limestones, and (more rarely) into schistose quartzites.

(3) The Pietra Verde group of Dr. Sterry Hunt, so far as the author has been able to ascertain, consists mainly of modified igneous rocks, of indeterminable date, and is at most only of local, if, indeed, it be of any classificatory value.

(4) Of the above three groups the uppermost has an immense development in the Italian Alps and in the Tyrol, north and south of the central range. It can, in fact, be traced, apparently at the top of the crystalline succession, from one end of the Alpine chain to the other.

(5) The middle group is not seldom either imperfectly developed or even wanting, appearing as if cut out by denudation. It was not seen in the traverse of the Franco-Italian Alps, except perhaps for a comparatively short distance on the eastern side, being probably concealed by Palæozoic and Mesozoic rocks on the western side. It is not very completely developed in the Eastern Tyrol, and seems to prevail especially in the Lepontine Alps, and on the southern side of the watershed.

(6) The lowest group is fairly well exposed, both in the French Alps and in the Central Tyrol.

(7) As a rule, the schists of the uppermost group had a sedimen-

tary origin. The schists and gneisses of the middle group very probably, in part at least, had a similar origin. In regard to the lowest group it is difficult, in the present state of our knowledge, to come to any conclusion.

(8) The slates and other rocks of clastic origin in the Alps, whether of Mesozoic or of Palæozoic age, though somewhat modified by pressure, are totally distinct from the true schists above mentioned, and it is only under very exceptional circumstances, and in very restricted areas, that there is the slightest difficulty in distinguishing between them. The evidence of the coarser fragmental material in these Palæozoic and later rocks indicates that the gneisses and crystalline schists of the Alps are very much more ancient than even the oldest of them.

(9) The remarks made by the author in his Presidential Address, 1886, as to the existence of a "cleavage-foliation" due to pressure, and a "stratification-foliation" of earlier date, which seemingly is the result of an original bedding, and as to the importance of distinguishing these structures (generally not a difficult thing), have been most fully confirmed. He is convinced that many of the contradictory statements and much of the confusion in regard to the origin and significance of foliation are due to the failure to recognize the distinctness of these two structures. In regard to them it may be admitted that sometimes "extremes meet," and a crystalline rock pulverized *in situ* is very difficult to separate from a greatly squeezed fine-grained sediment; but he believes these difficulties to be very local, probably only of a temporary character, and of little value for inductive purposes.

2. "On Fulgurites from Monte Viso." By Frank Rutley, Esq., F.G.S., Lecturer on Mineralogy in the Royal School of Mines.

The specimens described in this paper were collected by Mr. James Eccles, F.G.S., close to the summit of Monte Viso (12,680 feet above sea-level). They are fragments of a glaucophane-epidote schist, in which garnet, sphene, and occasionally diallage are present. Prof. Judd considers that the rock somewhat closely resembles the glaucophane schists and eclogites of the Ile de Groix.

The fragments are bounded by joint-planes or surfaces of easy fission, which are incrusted with minute pellets and thin films of fulgurite-glass forming the walls of lightning tubes. The glass was examined under the microscope (great care being taken to insure perfect isolation of the glass from the rest of the rock), and found to be, as a rule, remarkably pure, but in places not only gas-bubbles but also globulites occur, and the latter occasionally form longulites, and more rarely margarites. Microliths also are observable in some of the sections. In one section a minute rounded grain of schist containing a fragment of a strongly depolarizing crystal, probably epidote, appears to have been taken up in the glass.

Where the glass comes in contact with the rock the latter appears to have undergone no alteration beyond the development of a very narrow band of opaque white matter, which the author gave reason

for supposing to be due, not to the action of the lightning, but to a pre-existent segregation of sphene.

The occurrence of globulites, margarites, longulites, and microliths in the glass would seem to indicate a less sudden cooling than is assumed to be usual in such cases; for the glass presents no signs which would characterize a subsequent devitrification or secondary change, and the bodies just enumerated appear, unquestionably, to have been formed during the refrigeration of the fulgurite.

3. "On the Occurrence of a New Form of Tachylyte in Association with the Gabbro of Carrock Fell, in the Lake District." By T. T. Groom, Esq. Communicated by Prof. T. McKenny Hughes, M.A., F.G.S.

In this paper the author described an ancient but well-preserved glassy rock of basic composition which he had found as a vein associated with the gabbro of Carrock Fell. The rock was described macroscopically and microscopically, and a complete chemical analysis was given. The chemical composition resembled that of the more acid basalts and the augite-andesites, and approached especially closely to some continental basalts, analyses of which were added for comparison. Examined microscopically, the rock consisted of a globulitic and crystallitic glass-basis of green colour, containing spherules of quartz, spherulitic felspars, and an interesting series of granules and granular aggregates of augite, which likewise frequently assumed a spherulitic form. The rock was rendered microporphyritic by the sparing development of crystals (or skeleton-crystals) of plagioclase felspar, augite and quartz. The optical characters of each of the minerals were given. Owing to the mode of development and to the variety of its constituents, the rock possessed an exceedingly complicated structure. The order of crystallization was worked out, and it was pointed out that a second generation of each of the important constituents had arisen. The second generation of felspar was of a more acid type, and that of the quartz was devoid of fluid vesicles, and had crystallized out after the rest of the rock had solidified sufficiently to form cracks. Close physical and mineralogical relations with the gabbro were indicated, and the author had no doubt that the two were in actual connection with one another. The age was put down as probably Ordovician. A comparison of the rock with other basic rocks showed that it had affinities both with the glassy forms connected with the more volcanic members, and with the variolites of Durance found associated with diabase. The relation with the latter rock was especially marked, but important points of difference rendered a separation of the two necessary, and for the new type of rock thus recognized the name *Garrockite* was suggested. This rock might be looked upon as a *Quartz-Gabbro-Vitrophyre.*

CORRESPONDENCE.

ICHTHYOSAURUS ACUTIROSTRIS, ZETLANDICUS, & LONGIFRONS.

SIR,—On page 313 of the GEOLOGICAL MAGAZINE, Dec. III. Vol. V. 1888, I stated that I was "disposed to unite both *Ichthyosaurus Zetlandicus* and *I. longifrons* with *I. acutirostris*. Since that passage was written Prof. Karl von Zittel has been good enough to send me a figure of an entire skull of an *Ichthyosaurus* from the Upper Lias of Curcy, evidently belonging to *I. longifrons*, which I consider inseparable from *I. Zetlandicus*. This specimen differs, however, from *I. acutirostris* in its perfectly straight rostrum; and we have, therefore, a character which (if not merely sexual) will afford a valid distinction between the two forms. If *I. quadriscissus* of Quenstedt be identical with *I. acutirostris*, the name *I. Zetlandicus*, as earlier than *I. longifrons*, should be adopted for the straight-beaked form.

November 17th, 1888. R. LYDEKKER.

THE SERPENTINE OF THE LIZARD.

SIR,—There are two slight errors in Mr. Somervail's paper "On a Remarkable Dyke in the Serpentine of the Lizard" (p. 553 of last volume), which may mislead readers. They are contained in one sentence, "The dyke forms a portion of the 'granulitic group' of Prof. Bonney, which is now known to be of igneous origin." (1) I have never placed any of the rocks near Pentreath Beach in my "granulitic group," but speak of them more than once as belonging to the "hornblende schists." (2) For "which is now known to be" read "which is now known to include some rocks." The origin of the distinctly "banded gneissic" portion, like that of the banded hornblende schists, cannot be said to be yet known to any one, unless Mr. Somervail has been honoured with a special revelation on the subject. Most persons who have particularly worked at questions of this kind consider the origin of these rocks a very difficult and as yet unsolved problem. The speculations as to the origin and relations of the Lizard rocks, with which Mr. Somervail has favoured us, will no doubt meet with the attention which they deserve, regard being had to the wide experience of their author and his intimate knowledge of rock-structures. T. G. BONNEY.

THE GENUS *ASCOCERAS*.

SIR,—The figure which Prof. Lindström gives in the December Number,[1] of an *Ascoceras* from the Island of Gothland is a very instructive one—as it supplies some of the earlier septa which have hitherto been wanting and gives a final proof of their existence. It is thus completely confirmatory of the description of the genus which I gave on p. 61 of my British Fossil Cephalopoda. At the time of writing I was obliged to say "the earlier part is unknown"—which still remains partially true—since only three chambers of

[1] GEOL. MAG. 1888, Dec. III. Vol. V. p. 533, Woodcut.

the ordinary type are seen in the new specimen; but I had to add "the body chamber and the last few septal chambers only [those which are distorted] being preserved in association." This is now no longer true, but the remainder of my description was entirely based on the probability, not to say the certainty, of such a specimen being ultimately found. It runs, "The earlier septa are of the ordinary kind, with very little convexity and the siphuncle is excentric, in some of large size . . . The last few chambers are distorted and their dorsal portions are seldom seen." These dorsal portions, as in the specimen figured by Barrande (Syst. Sil. de la Bohême, vol. ii. p. 513), are well shown in the new specimen. I arrived at the same conclusion as Professor Lindström—that the *Ascoceras* "is by no means the simplest form of Cephalopod, but the most abnormal," and included it with *Poterioceras* and others in the group *Inflati*, the genus being characterized by having its "later septa distorted." The group is said to *diverge* from the *Conici, i.e.* the *Orthocerata*, etc., and to be remarkable for the loss of the early septa.

It is satisfactory that in all these points the new specimens from Gothland confirm the previous observations. J. F. Blake.

THE MONIAN SYSTEM.

Sir,—I feel greatly indebted to Dr. Callaway for introducing the Monian System to the notice of your readers. It was through his advice I went to Anglesey, and he naturally takes a fatherly interest in the result.

There are, however, certain points in his "Notes" which call for explanation or reply.

1. I am happy to recognize that Dr. Callaway, in 1887, quite independently of my observations, came to the conclusion that the hornblende-schists were of igneous origin, notwithstanding that such a conclusion entirely overthrew his reading of the succession in the "gneissic series." I must even confess that he is bolder than I am, for my statement that these schists are igneous, is made in fear and trembling; for though I am forced to it by the stratigraphy, I know it would have been laughed at a few years ago. Nor can I get as far as "foliated felsites," those so considered by Dr. Callaway being compressed and indurated examples of the ordinary mica-schists of the district.

2. As to Parys Mountain, there are two other writers' opinions to consider besides Dr. Callaway's.

3. As to the Llanfechell Grit. I acknowledge it would be of some importance if it could be shown that any large part of the upper portion of the series was made up of fragments of the lower; but after all the Llanfechell Grits are merely subordinate bands in a long series, and there are no conglomerates in association with them, so that at best any included fragments would be poor evidence. Moreover, it seems quite common in these old rocks, for the earlier deposits to be rapidly altered and to contribute to the later. Thus the con-

glomerate of Bull Bay is made of the underlying quartz rock. The fragments in the "agglomerates" or "conglomerates" of Llangefni are like some of the neighbouring rocks, the Bangor beds are full of fragments of rocks very similar to other parts of the same series, and the conglomerate of Moel Tryfaen is largely composed of the immediately preceding Cambrian slates. I do not, therefore, give much weight to any argument from such a grit. I only dealt with it because it was confessedly at first the *only* argument for there being two groups of Precambrian rocks in Anglesey. If the rock is discussed, I have to say that of course Prof. Bonney's *description* is accurate. The fragments do "much resemble some of the finer-grained schists of Anglesey;" but they resemble those parts which have been *entirely re-formed;* such entire re-formation occurs sometimes in bands parallel to the lamination, sometimes in veins crossing it, and is not confined to the older part of the series, but affects many other parts. The veins, like the rest of the rock, have formed under a pressure that has induced an orientation of the micaceous ingredient. We cannot, therefore, identify the fragments with any definite rock.

4. The rocks near Llyn Irefwll. In this case, again, I should have said nothing except for the stress Dr. Callaway lays upon the locality. I twice failed to find the exact spot referred to, though the whole structure of the surrounding rocks seemed clear. Only by the minutest directions was I able to find a spot where some slaty-looking rock contained fragments of granite, and seems continuous with the diabase which forms part of several bosses. All these figure as "slate" in Dr. Callaway's paper. Several slides have been examined and prove to be diabase—hence "some of the slates of Dr. Callaway are diabase." Where the granitic fragments are found, this diabase has become more or less hornblendic, or dioritic—or it may be that the containing rock is a distinct one. In any case, fragments of granite are contained in a slaty-looking rock which is not a slate. They must also be contained in a true slate, since such is their matrix as described by Prof. Bonney; but this slate is certainly not the diabase ridge figured as Pebidian by Dr. Callaway. It is really not worth while pursuing the question any further.

5. With regard to the areas where there is a passage between Dr. Callaway's lower and upper groups, his observations are rather special pleading, because he selects two places, nearly the only two, where the succession is confessedly broken by faults, and gives these as examples; whereas in both these places the supposed succession is stated to be entirely made out from what is *observed* abundantly elsewhere.

6. As to the applicability of the Monian system to other regions, it is obvious that our first business is to thoroughly understand the development of a series of rocks in the place where the connection of one part with another is most fully displayed, and such a place is Anglesey, where the succession and stratigraphy in many places is comparatively clear. It is a later work to correlate other regions with the type, the probable result only being briefly indicated in my

paper. The reason for correlating the Longmynd rocks with the Upper Monian are, first, that they are certainly pre-Cambrian, especially since the discovery by Prof. Lapworth of the lowest Cambrian fauna in other rocks in the immediate neighbourhood, and, secondly, that the only certain fossils recorded from the Longmynd, *Arenicolites didyma*, are also recorded from the rocks of Bray Head. It is also to be noted that as the "Uriconian" is to a large extent volcanic, there need not be much of a gap between it and the "Longmyndian." By some curious effort of the imagination Dr. Callaway says "Uriconian and Malvernian are lumped together as Middle Monian," but I cannot find that I have anywhere mentioned the "Malvernian," as I know too little of that district and the descriptions are too discordant to make it safe even to venture upon a probability. It may not be Monian at all.

If Dr. Callaway has a fancy to call the different divisions of the Monian by names derived from other districts, there can be no objection, provided we first make sure of the correlation. I am perfectly satisfied with their all forming parts of a larger group or system—the Monian.

I may add that as these rocks have a quite distinct character from the true Hebridean, or the general type of gneisses, I was much delighted to find that so many foreign geologists, who visited Anglesey in September last, recognized their resemblance to rocks of their several districts which occur immediately beneath their lowest fossiliferous horizons. J. F. Blake.

Dec., 1888.

UNIFORMITY IN SCIENTIFIC BIBLIOGRAPHY.

Sir,—Having been for some time engaged in preparing a bibliography of earthquake-literature, I can fully endorse the necessity of Mr. C. D. Sherborn's plea for uniformity in the quotation of abbreviated titles of scientific journals. The increasing number and importance of works of this class render this and other unsettled points in bibliography worthy of attention and discussion; and I would venture to suggest that the British Association Committee on Zoological Nomenclature could find a useful successor in a Committee for securing Uniformity in Scientific Bibliography.

May I be allowed to offer here a few remarks on this subject?

Abbreviated Titles.—Besides a mere hap-hazard choice two courses are open in the selection of abbreviated titles.

(1) We may adopt that in use amongst the members of the Society issuing the journal, as "Phil. Trans." or "Comptes Rendus." Familiarity in a few cases and established custom are in favour of the retention of this system, but it has the obvious disadvantage of not representing at a glance the complete title of an unknown journal, for it omits the name of the society. Moreover, contractions founded on such words as "Transactions" or "Proceedings," common to a great number of societies, are objectionable.

(2) The abbreviations may be formed on a uniform plan from the full title of the journal. That adopted in the Geological Record